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MACHINE DESIGN

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ER 29, 1956
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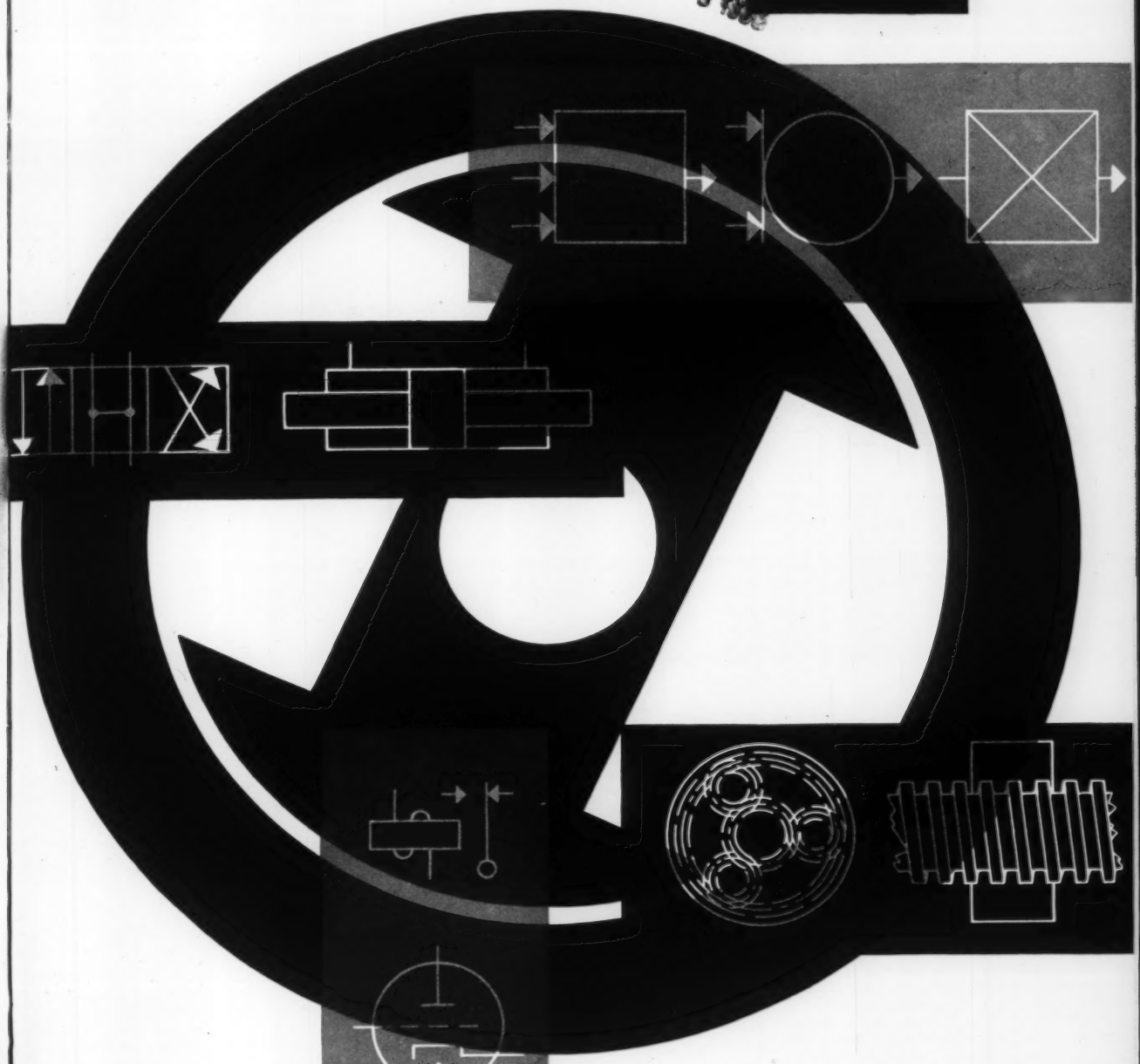

Drives and Controls

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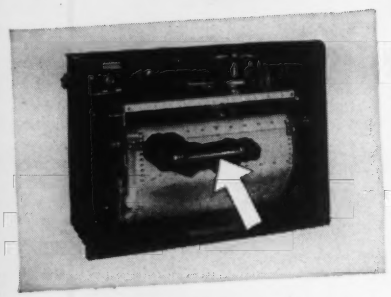
FLEXIBLE SHAFT IDEAS for ENGINEERS

Flexible Shafts simplify manufacturing operations — lead to improved designs

Cost-savings possibilities are many when you design with these useful mechanical elements

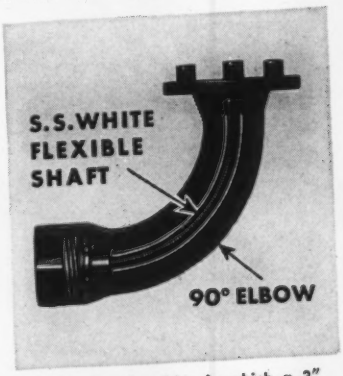


Giving alignment problems the "go-by"

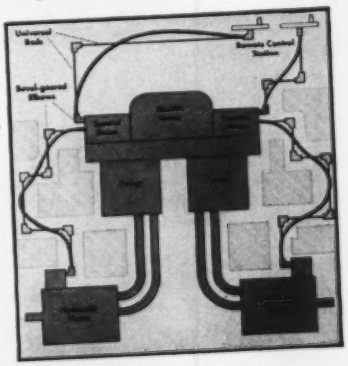
NOT ONLY DOES a flexible shaft provide a vibrationless drive in this sensitive recording pyrometer, but it eliminates the need for accurate alignment of the connected spindles. The ability of a flexible shaft to operate under conditions of misalignment is a feature that is of extreme importance in many remote control and power drive installations.

Here is a bulletin every designer should have

Bulletin 5601 contains the latest information on flexible shafts. Included are full details on how to select and apply power drive and remote control flexible shafts as well as up-to-date tables showing flexible shaft sizes and characteristics. Send for a copy.



A truck recorder drive in which a 3" flexible shaft replaced a set of bevel gears and straight shafts. Result: fewer parts, lower cost and elimination of failures caused by high starting torque of the gears.



4 standard flexible shafts replaced the 35 parts formerly used to control this dual hydraulic power unit. Result: a 90% cost savings and 100% improved performance.

NO OTHER SINGLE MECHANICAL ELEMENT solves power drive and remote control problems as simply and economically as an S.S.White flexible shaft.

Savings through Simplification

For instance, the ability of an S.S.White flexible shaft to operate around turns and under conditions of misalignment is a big help in simplifying drive or control setups. It means that a single flexible shaft can often be used in place of whole systems of bevel and worm gears, solid shafts, universals, etc. Naturally, with fewer parts to handle, production time and costs can be trimmed.

Improved Designs

Simplification is not the only advantage offered by an S.S.White flexible shaft. It gives greater leeway in locating coupled parts to insure greater efficiency, easier operation, greater compactness, or more attractive appearance.

Reduced Layout Time

Not the least of a flexible shaft's advantages, is the ease with which it can be applied. There are no gear ratios to work out—no alignment problems—no worries about tolerances on bearing and journal fits, about special machining, etc. And, the wide range of physical characteristics and sizes available, make it easy to meet a diversity of requirements.

F6-4

FIRST NAME IN FLEXIBLE SHAFTS

S.S.White

S. S. WHITE INDUSTRIAL DIVISION, DEPT. 4, 10 EAST 40th ST., NEW YORK 16, N.Y.

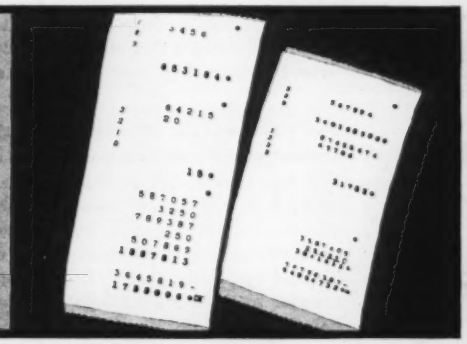
Western Office: 1839 West Pico Blvd., Los Angeles 6, Calif.

Circle 501 on page 19

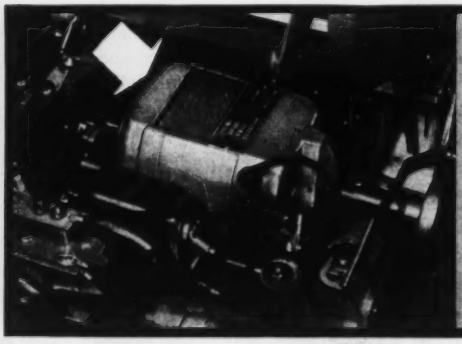
Why Bodine Motors were selected for Remington Rand automatic calculators

1 This is a Remington Rand model "99" printing calculator. It's a fully automatic machine.

2 Just a light touch from the operator and it multiplies, divides, adds and subtracts.



3 It gives her the answer without printing all the figures involved in calculation, only the essential figures are printed.



4 The mechanism of the Remington Rand automatic printing calculator is powered by this series wound Bodine motor.

5 This gentleman is Mr. B. H. Tingley, Remington Rand's development engineer for adding and calculating machines.

"Our requirements demand a motor with a high torque for its size. The Bodine motor meets these requirements without excessive temperature rise. We have found that Bodine motors, used in our Adding and Calculating Machines, to be exceptional for reliability and performance."

BODINE

BODINE

fractional horsepower

MOTORS

6 Why are Bodine Motors used by Remington Rand? Mr. Tingley gives his answer above...

7 Be sure your motor is as good as your product. Contact Bodine Electric Co., 2258 W. Ohio St., Chicago...or check your Sweet's file.

BODINE MANUFACTURES FRACTIONAL HORSEPOWER ELECTRIC MOTORS FOR:

adding machines
letter openers
sanders
vending machines
exhaust fans
duplicating machines
hand dryers
portable tools
sound recorders
air conditioners
check protectors
respirators
voltage regulators
x-ray timers
traffic signal timers
stirrers
calculating machines
envelope sealers
diesel governors

. . . and for many other applications.

Ask for a sample copy of 'The Motorgram,' a bi-monthly publication discussing the application and design of fractional horsepower electric motors.

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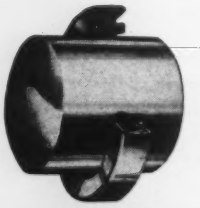
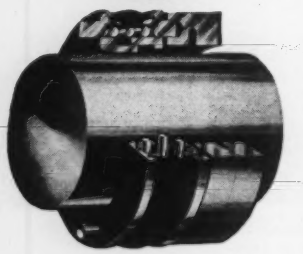
C/R cooperative research

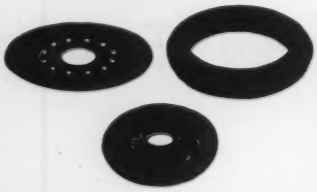
covers this wide range of products



SHAFT-TYPE OIL SEALS More than 20 types, forming over 7,500 size combinations for shafts from ¼" to 50" O.D., are available — thousands from stock. These seals are used for the vast majority of shaft sealing problems from simplest dust exclusion to high-speed, high-temperature fluid retention and foreign matter exclusion under extremely rugged operation where high sealing efficiency must be maintained over long service life.



END FACE SEALS For critical sealing problems outside the capabilities of shaft-type seals, there are C/R End Face Seals, which operate on the principle that two smooth, flat surfaces, one rotating on the other at right angles to the shaft, form a leakproof seal. They require minimum pressure to maintain face contact, create minimum friction, heat and power loss, and give unsurpassed performance under the most severe conditions.
Typical applications of C/R End Face Seals include: sealing track rollers of crawler tractors; sealing high-speed accessory drives in aircraft; sealing medium speed applications such as gear cases of washing machines, dishwashers and similar home appliances.



SIRVENE SYNTHETIC RUBBER PRODUCTS The advanced level of compounding and molding elastomers and special materials to critical tolerances achieved by C/R Sirvene Engineers is a widely established fact. They will design, compound and produce a part to your exact specifications of hardness, elasticity, and resistance to aging, temperature, oils, solvents or chemicals — with dimensional uniformity and consistent high quality, regardless of quantity. Holding to extremely close tolerances is standard procedure. A typical list of products includes oil seal packings, diaphragms, cups, boots, gaskets, plugs, impellers, valve inserts and way wipers — to name but a few. The experience and facilities available to you from C/R's Sirvene Division are unrivaled in the industry.

SIRVIS-CONPOR MECHANICAL LEATHER PRODUCTS The typical range of mechanical leather products includes oil seal packings, cups, boots, washers, gaskets, couplings and valve discs, but encompasses any part wherein high tensile strength, flexibility, high resistance to pressure, wear, shock, and vibration are desired. Cups of C/R's Conpor impregnated Sirvis leather products are operating at pressures up to 10,000 p.s.i. They are insoluble in most hydraulic oils and compatible with a wide range of other oils, solvents and gases. C/R boots of Sirvis leather, canvas, nylon or elastomer impregnated fabric can be produced in sizes two stories high or not bigger than your thumb for use in the protection of eccentric, universal or reciprocating action. Whatever your sealing or protection problem, bring it to Chicago Rawhide. C/R Engineers are constantly developing new mechanical leather designs for special and universal application.

Please write direct or contact your nearest C/R sales engineer about your problem in fluid sealing or related fields.

CHICAGO RAWHIDE MANUFACTURING CO.

Offices in 55 principal cities. See your telephone book.

In Canada: Chicago Rawhide Manufacturing Co., Ltd., Hamilton, Ontario
Export Sales: Geon International Corp., Great Neck, New York

C/R Products: C/R Shaft and End Face Seals • Sirvene (synthetic rubber) molded parts • Sirvis-Conpor mechanical leather cups, packings, boots • C/R Non-metallic Gears • C/R Rawhide and nylon hammers.

C/R CHICAGO RAWHIDE

THE PROFESSIONAL JOURNAL
FOR ENGINEERS AND DESIGNERS

MACHINE DESIGN

November 29, 1956
Volume 28—No. 24

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Subscriptions in United States, possessions, and Canada for home-addressed copies and copies not qualified under above rules: One year, $10. Single copies $1.00. Other countries: One year, $25. Published every other Thursday and copyrighted 1956 by Penton Publishing Co., Penton Bldg., Cleveland 13, Ohio. Accepted as Controlled Circulation publication at Cleveland, Ohio.

When requesting changes of address, etc., please allow four to six weeks for processing.

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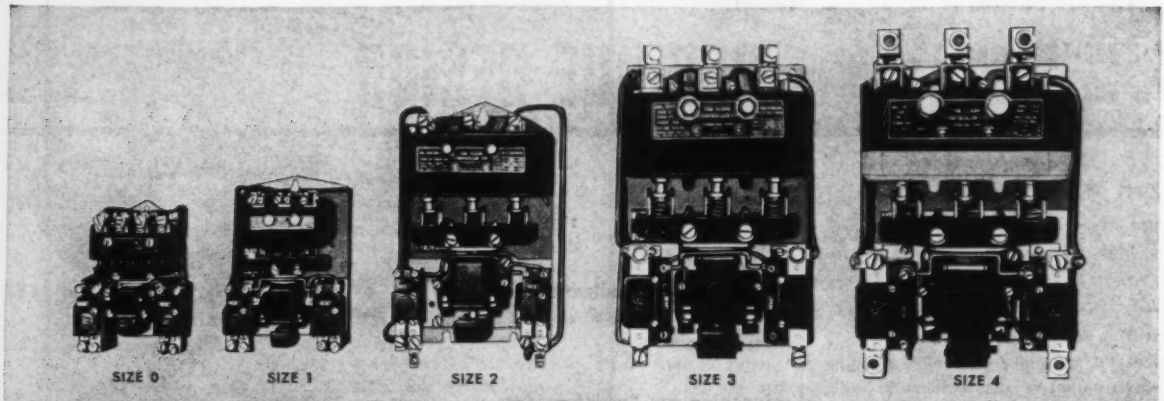
XUM

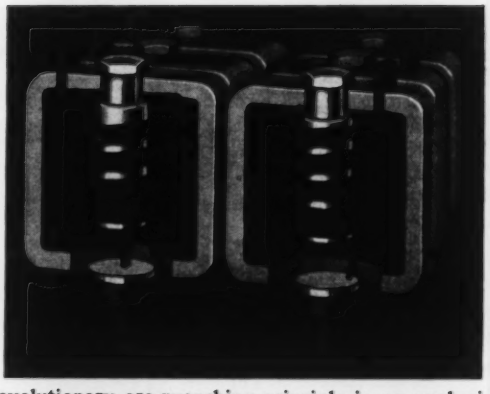


CLARK Type "CY" Starters now available in sizes

0 to 4

With the addition of the new size 4, the famous CLARK line of Type "CY" Magnetic Motor Starters now comprises the full range from 0 to 4. This means that Clark starters of the proven "CY" design incorporating vertical lift magnets are now available for more than 95% of industry's AC requirements. For installations requiring sizes 5 and larger, Clark will continue to supply dependable clapper-type starters.

Clark Type "CY" starters have many outstanding design features for more dependable operation, less maintenance and longer life. For example—rugged construction with twin-break contacts means more trouble-free service . . . contacts can be inspected without tools . . . movable and stationary contacts can be removed and replaced quickly, coils changed and the entire magnet assembly removed—all from the front—without special tools and without removing the starter from the cabinet or panel.



Revolutionary arc-quenching principle is an exclusive feature of all Clark Type "CY" starters sizes 2 and larger. It combines twin-break contacts with strong multi-turn magnetic blowouts which force the arc to rotate—alternately lengthened and confined—so that it moves continuously from a hot to a cold spot on the contact surfaces. This practically eliminates metal build-up or pitting and greatly increases contact life.

For complete information contact your nearest Clark sales office or write us direct.

The CLARK CONTROLLER Company

Engineered Electrical Control

1146 East 152nd Street • • Cleveland 10, Ohio

IN CANADA: CANADIAN CONTROLLERS, LIMITED • MAIN OFFICES AND PLANT, TORONTO

Circle 506 on page 19

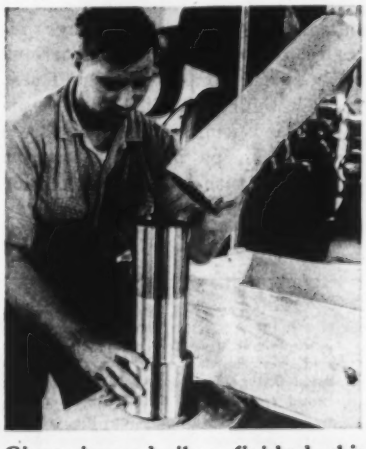
Engineering News Roundup

Big Cap Screws Made For Wind Tunnel Nozzle

CLEVELAND, O.—Fifty giant hexagonal socket-head cap screws, measuring 4½ in. diam and having a combined weight of 2 tons, will be used in the supersonic nozzle assembly of the largest propulsion wind tunnel in the U.S. The tunnel is being constructed by the Army Corps of Engineers for the Air Force at the Arnold Engineering Development Center, Tullahoma, Tenn. The screws are being made by the Cleveland Cap Screw Co.

Two lengths of screws are being made: 10¾ in. and 9½ in. Head diameters are 5½ in. and the internal hexagonal sockets are 2½ in. across flats. Each screw is turned from a 125-lb blank of high-carbon chrome molybdenum steel, AISI 4140. Finished weight per screw is about 80 lb.

Despite the size of the screws, the threads are Class 3 fit. Following heat treatment to a Rockwell C hardness of 38-42, the screws are ground to a 32 mu in. finish and silver plated 0.005 to 0.008-in. thick over a nickel undercoat.



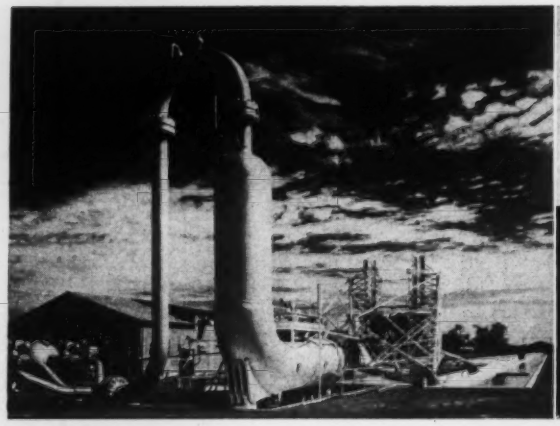
Giant size and silver finished, this is one of 50 cap screws to be used in a new supersonic wind tunnel nozzle. Finished weight of the 4½ in. diam screw is 80 lb.

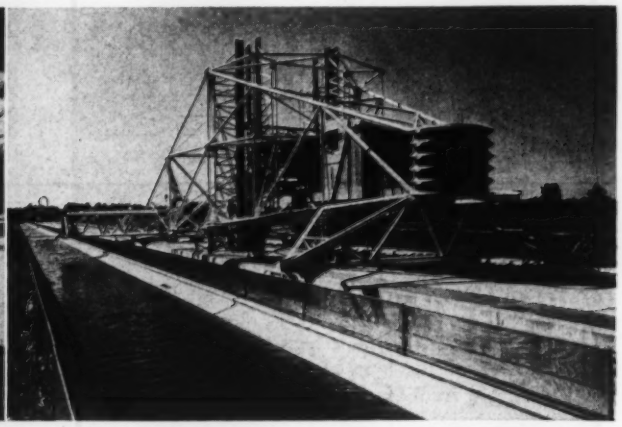
The variable nozzle in which the screws are used will produce speeds between Mach 1.5 and an estimated Mach 5.0. Test section of the tunnel will measure 16 by 16 ft. Four motors on one shaft drive the tunnel compressor.

TAILORED TO THEIR JOBS, these two new Lockheed planes show the contrast in design of aircraft developed for different missions. The 1649A Super Constellation in the foreground is the longest-range airplane in the world, capable of flights up to 6300 miles without consuming fuel reserves. Its 150-ft wing, with aspect ratio of 12, is the longest of any transport, carries 9600 gallons of fuel. The 1049H in the background has the same fuselage dimensions as the airliner but is intended primarily for cargo. Its 123-ft wing has an aspect ratio of 8.5, lifts 20 tons of cargo.

Aircraft Landings Simulated on Tester Driven by Water Jet

LANGLEY FIELD, VA.—Unique new research equipment with power sufficient to hurl loads representing the weight of B-29 bombers up to take-off speed in less than 2 seconds is now in operation at the





New facility of the NACA at Langley Field, Va., is this Landing Loads Track for testing aircraft landing gear, wheels and tires. The carriage is catapulted along a 2200-ft track at speeds up to 150 mph. The catapult consists of a single jet of water forced from an L-shaped tank (left) into a bucket on the carriage. An arm on the carriage (right) will also tow models on hydrodynamic test through the water basin next to the track.

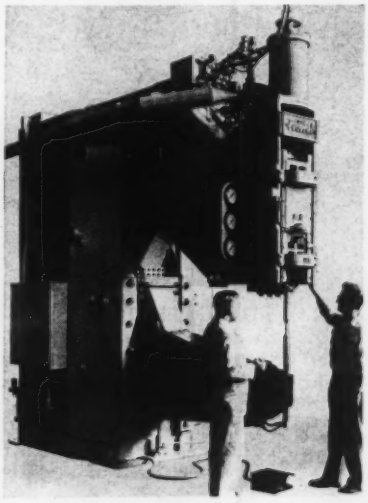
Langley Aeronautical Laboratory of the National Advisory Committee for Aeronautics. Known as the Landing Loads Track, the testing installation was publicly demonstrated for the first time recently during the NACA's 1956 Triennial Inspection of the Langley Laboratory.

Principal component of the tester is a 50-ton carriage which is catapulted by a hydraulic jet at speeds up to 150 mph along a 2200-ft track. The carriage is halted during the last 600 ft of its run by 20 arresting gears similar to those on aircraft carriers. Tests will be made of full-scale landing gear and other aircraft parts.

The test carriage, as big as a house, serves as a frame to transport the drop test rig on which landing gear is mounted. When ready for catapulting, the carriage is positioned at a nozzle on an L-shaped tank. Water in the tank is under 3260 psi air pressure.

On catapulting, water is emitted through the nozzle at a maximum velocity of 660 fps by a remote-controlled, quick-opening valve. Carriage velocity is governed by both the length of time the valve is open and by the air pressure. As the carriage is fired, the water jet is reversed by a specially shaped bucket attached to the main carriage. The jet stream produces a thrust of 400,000 lb, accelerating the carriage to 150 mph within 400 ft and 3½ seconds.

Instruments provide data on the shock absorbing properties of landing gear, the physical nature of skidding during wheel spin, the elastic behavior of tires in yawed rolling, and similar characteristics.



LARGEST RESISTANCE SPOT WELDER of its type is the claim for this new model developed by Federal Machine and Welder Co. The machine is 13½ ft high; weighs more than 58,000 lb. Special throat of approximately 2100 sq in. accommodates a portion of the tail section of the largest commercial jet airliner, now under construction. Three-phase unipolar transformer in the welder supplies 100,000 amp and is also the largest of its type.

Photographic Dye Process Used for Optical Reticles

PASADENA, CALIF.—A process for making optical reticles and similar precise markings on glass uses photographic dye to produce image elements as small as 5 microns. Called Diadur, the process is being introduced in the U. S. for the first time by Bushnell Optical Enterprises by arrangement with its German originator.

The Diadur process reproduces a master line drawing on glass as a precise photographic dye image more durable than the glass itself. It is claimed that a master pattern can be reduced photographically to microscopic proportions without loss of detail. The finest cross-hatching in one example is 5 microns wide. Measuring scale reticles can be made as long as 1200 mm with a linear accuracy of 1 micron in 250 mm.

Advantages claimed for the proc-

Front Cover

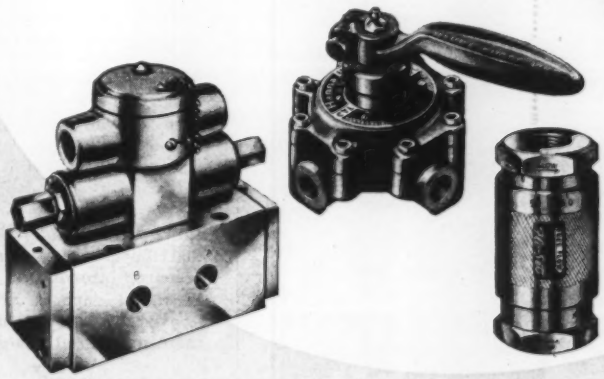
Since this is a special issue on drives and controls, it's only natural that artist George Farnsworth has picked a broad cross section of drive and control devices to display on the front cover. Symbolically portrayed are hydraulic gimmicks, mechanical components, and electrical equipment. Also included are several static electrical controls, the subject of John Ponstingl's feature article beginning on Page 89.

HANNA CYLINDERS

There is a complete line of Hanna Cylinders to suit all requirements of size and mounting . . . in capacities up to 250 psi for low pressure air or hydraulic operation, and up to 1500 psi hydraulic.

. . . finest combination for Dependable Fluid Power and Reliable Controls

HANNA VALVES



Designed to assure most efficient control, there are many types and sizes of Hanna Valves available for hand, foot and electric operation, for automatic, remote and speed controls.

It may not take over half a century to design and build a superior line of cylinders and valves . . . but the experience a company compounds in that time surely helps. Hanna has that background.

What does it mean to You, today—in terms of cylinders and control valves?—Basically these important things:

- Products designed and manufactured to the very highest standards of performance . . . not built down to a price—although they are competitive.
- A line so complete that you can specify a "standard" Hanna cylinder or valve to suit your "special" jobs.
- A plant engineering staff that backs a nationwide regional engineering-sales organization to help you quickly solve difficult problems—and to follow through on all your "needed now" requirements. Many Hanna Representatives stock the standard sizes and types of Hanna Products—the Hanna Plant, of course, does, too.

Whether you need cylinders and controls for equipment that is for resale, or for your own plant use . . . call or write your Hanna Representative (see classified telephone directory or Thomas' Register) or write us direct.

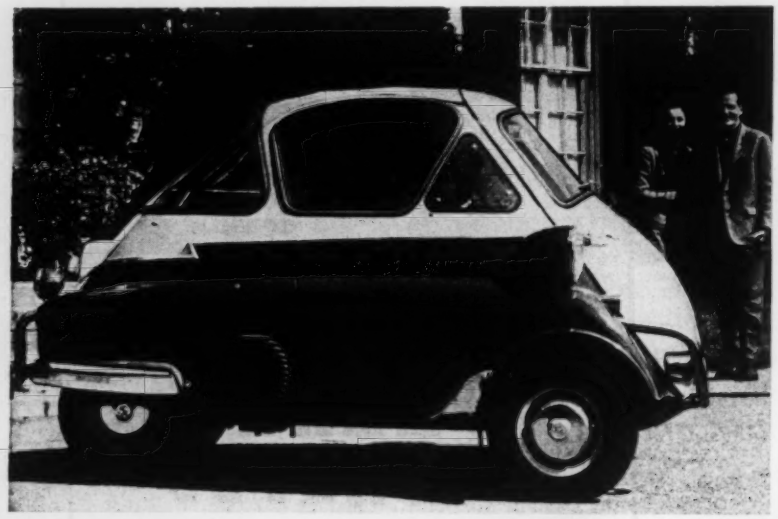
Hanna Engineering Works

HYDRAULIC AND PNEUMATIC EQUIPMENT . . . CYLINDERS . . . VALVES

1751 Elston Avenue, Chicago 22, Illinois

Circle 507 on page 19

ess are that identical duplicate reticles can be made in any quantity at low cost. No protective cover glass need be used with Diadur reticles, and images may be photographic negatives or positives. Degree of reflection may range from 6 to 60 per cent.



New entry in the small car market is this German-built Isetta. It can be parked in a 7½ ft space and can travel 60 miles on one gallon of gas.

Small Car for Three Features Low Cost, Easy Handling

NEW YORK, N. Y.—Recently introduced to the American car market is the German-built Isetta selling for less than $1000. Maximum speed over 50 mph and gas economy of 60 miles per gallon are claimed.

The fan-cooled, four-stroke engine has 7 to 1 compression ratio and is rated 13 bhp. Transmission provides four forward speeds, one reverse. Front wheels have coil springs and rear wheels have quarter elliptic leaf springs. Tire size is 4.80-10.

Wheelbase is 58 in., length 89.9 in., width 54.3 in., height 52.6 in., weight 770 lb. The car can turn completely in a 24-ft circle.

Main entrance to the Isetta is the single front door. Steering wheel tilts away from driver. Seat is wide enough for three persons. Sun roof pulls back for clear days.

General Electric Co. has opened its $1,000,000 bearing and lubricant center in Schenectady, N. Y. The new center is equipped to carry on advanced development work relating to atomic submarines, jet engines, missiles and satellites, as well as to provide a facility for improving turbines, motors and household appliances. General Electric officials foresee the study of revolutionary concepts in bearing design, such as air bearings and the use of molten metal and molten glass as supersonic lubricants.

Topics

New dual control system for driving instruction can be installed in minutes, permits the instructor to step on the clutch or brake, and costs just $25 for standard or $30 for automatic transmissions. These things would also make dandy Christmas presents for back-seat drivers.

• • •

For the GI, a foxhole digger has been developed to make a 4½-ft diam, 4-ft deep hole in 90 seconds. A rocket is driven into the ground at the proposed foxhole site and explodes in 15 seconds, leaving the required hole.

• • •

Nobel Prize in physics for 1956 was awarded to three Bell Telephone Co. laboratories researchers for development of the transistor.

• • •

U. S. atomic-powered bomber may not get off the ground until 1960, two years later than originally planned and, very likely, after Russia has such a plane flying. Main reason reported for deferring completion of an A-bomber is that high priority is being given to designing a so-called "chemical" plane powered by new super fuels.

• • •

Government Research Information program has undertaken wider distribution of unclassified basic research information. Some 20,000 technical reports are issued annually by groups doing government-sponsored research.

• • •

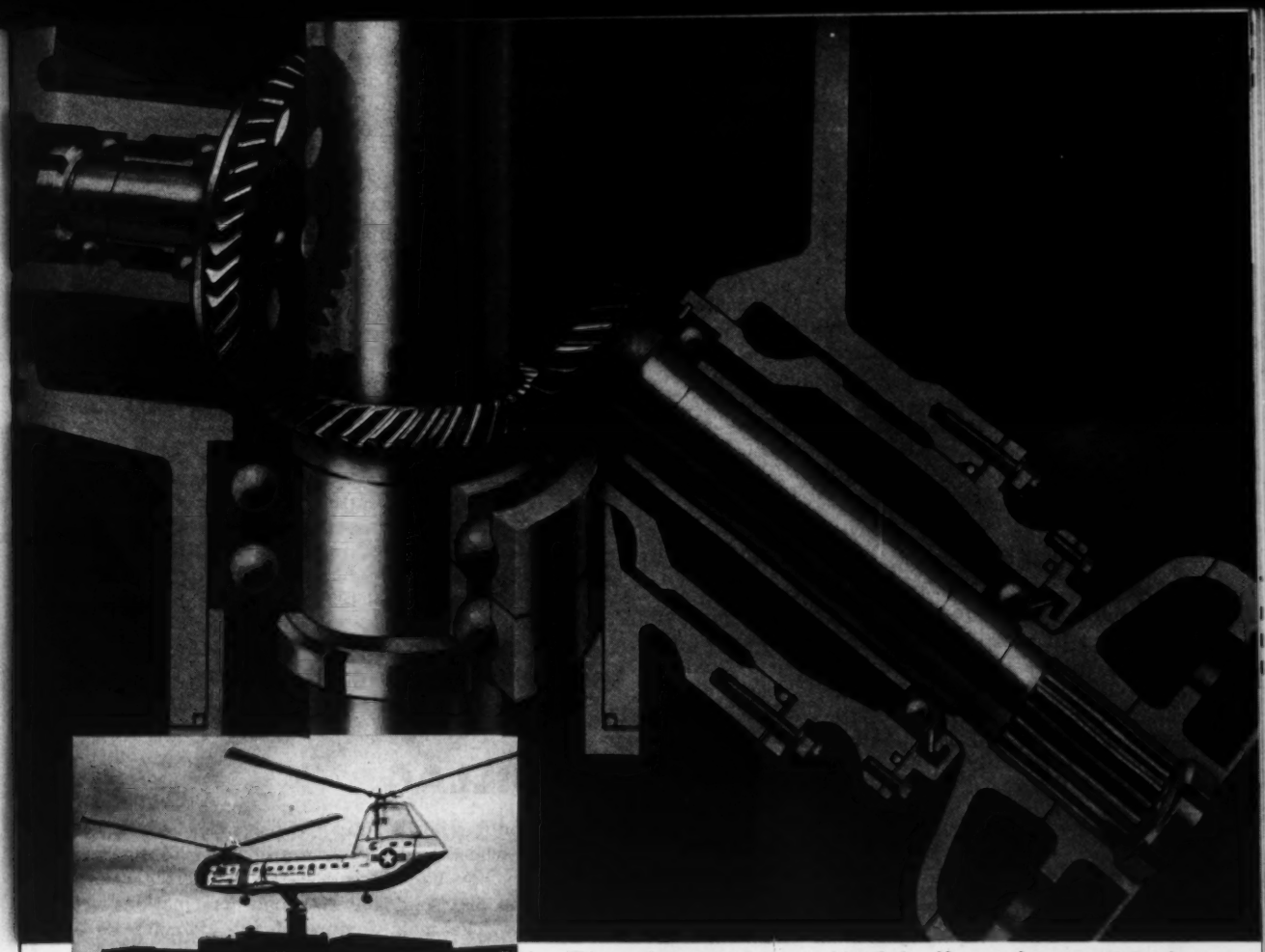
First-run movies on TV are contemplated by Bartlesville, Okla., viewers. Features being shown locally are to be sent to subscribers throughout the city by means of a cable and will be shown on a channel not used for commercial broadcasting.

• • •

Studebaker-Packard Corp. enters the heavy-duty truck field with 1957 models. They range from ½-ton pickups to 2-ton models.

• • •

False-alarm foiling is an advantage of a recently patented fire alarm box. To turn in an alarm, a person must enter a booth-like structure and close the door. Pulling the alarm lever locks him inside the booth, where he stays until firemen arrive and receive further instructions from him. Or vice versa, in the case of a false alarm.



This angular gear arrangement drives both a blower and a pump on a twin rotor helicopter. Gleason engineers made design and production recommendations and produced prototypes for the manufacturer.
Combination: 18 x 34 x 41; D.P. :7.56; Face ½"; Tooth Spacing—within .0003".

You can solve your angular power transmission problems, too!

The designers of this gear unit achieve greater flexibility within a limited amount of space by placing the drive shafts at an angle and using one source of power to drive two auxiliary units.

Perhaps a similar gear drive would make your product designs more flexible. Such bevel gear drives permit a more compact design requiring less weight and the ability to carry higher loads.

Our engineers are ready to help you work out applications for bevel and hypoid gears—just as they helped the helicopter manufacturer with the design illustrated above.

We recommended the proper gear sizes and reviewed the mountings and lubrication for the drive. Then we produced and tested prototypes of the unit.

If you would like to discuss an application with one of our representatives, please write. You will also find these Gleason Technical Handbooks helpful: 20° Straight Bevel Gear System; Spiral Bevel Gear System; ZEROL Bevel System.

GLEASON WORKS

Builders of bevel gear machinery for over 90 years

1000 UNIVERSITY AVE., ROCHESTER 3, N.Y.

Circle 508 on page 19

Rounding Up the 1957 Automobiles—2

LIKE other 1957 models, the six cars described in this issue feature new styling. Emphasis is placed on longer, lower body styles, 14-in. wheels, rear fender fins and increased windshield area. Several makers are adding new models to their lines.

Mechanical improvements are numerous, including redesigned brakes, carburetors that increase horsepower, new suspension systems and a supercharger.

PLYMOUTH

Overall heights of 1957 Plymouths are as much as 5 in. lower than corresponding 1956 models. Wheelbase has been lengthened 3 in. in standard models, 7 in. in station wagons. Four series, including 33 models, are available. The 12 station wagons include nine-passenger models which have a rear-facing third

seat. The second and third seats of all station wagons fold into the floor to provide maximum cargo space.

Engine Specifications

	Powerflow 6*	Hy-Fire V-8†
Type	L-head, In-Line	OHV, Vee
No. cyls.	6	8
Bore & stroke (in.)	3.25 x 4.63	3.75 x 3.13
Displ. (cu in.)	230	277
Comp. ratio	8.0 to 1	8.0 to 1
Bhp, max	132 @ 3600	197 @ 4400
Torque, max (lb-ft)	205 @ 1600	270 @ 2400

	Fury 301§	Fury 301 Quad‡
Type	OHV, Vee	OHV, Vee
No. cyls.	8	8
Bore & stroke (in.)	3.91 x 3.13	3.91 x 3.13
Displ. (cu in.)	301	301
Comp. ratio	8.5 to 1	8.5 to 1
Bhp, max	215 @ 4400	235 @ 4400
Torque, max (lb-ft)	285 @ 2800	305 @ 2800

*Standard on all 6-cyl. models.
†Standard on Plaza V-8 models.
§Standard on Savoy, Belvedere and Suburban V-8 models.
‡Optional on all V-8 models.

Size and Weight

	Suburban Models	All Others
Wheelbase (in.)	122	118
Length (in.)	213.1	204.6
Width (in.)	78.2	78.2
Height (in.)	56.9	56.6*
Weight (lb)	....	3420*

*Four-door sedan.

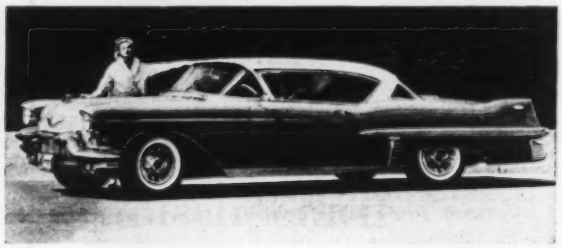
Ball-joint, torsion-bar suspension is incorporated in the front end of the Plymouth; leaf springs have been relocated in the rear. New frames have five heavy crossmembers to provide strength. Low-pressure, 14-in. tires hold more air than previous tires and absorb more shock.

Greater displacement and higher compression ratios have increased horsepower. Conventional manual shift, overdrive, pushbutton Power Flite and pushbutton Torque-Flite transmissions are available. New 11-in. total-contact brakes work with 25 per cent less effort than previous types.

Other features of the 1957 Plymouth include greater glass area; a windshield wiper that clears more area; high-capacity, high-pressure cooling system; and optional swivel-mounted defrosters and heater that permit warm air to be directed where desired.

CADILLAC

The Cadillac line for 1957 includes ten body styles on three wheelbases. Two cars in the 1957 line are new four-door hardtop models. In exterior colors, more than 500 solid and two-tone combinations are available. The main feature of the 1957 line is a



new body frame which has enab'ed the overall height of most models to be lowered as much as 3 in.

The new Cadillac body is secured to outrigger mountings where formerly the body was secured to side rails. The new frame is called a tubular center

Engine Specifications

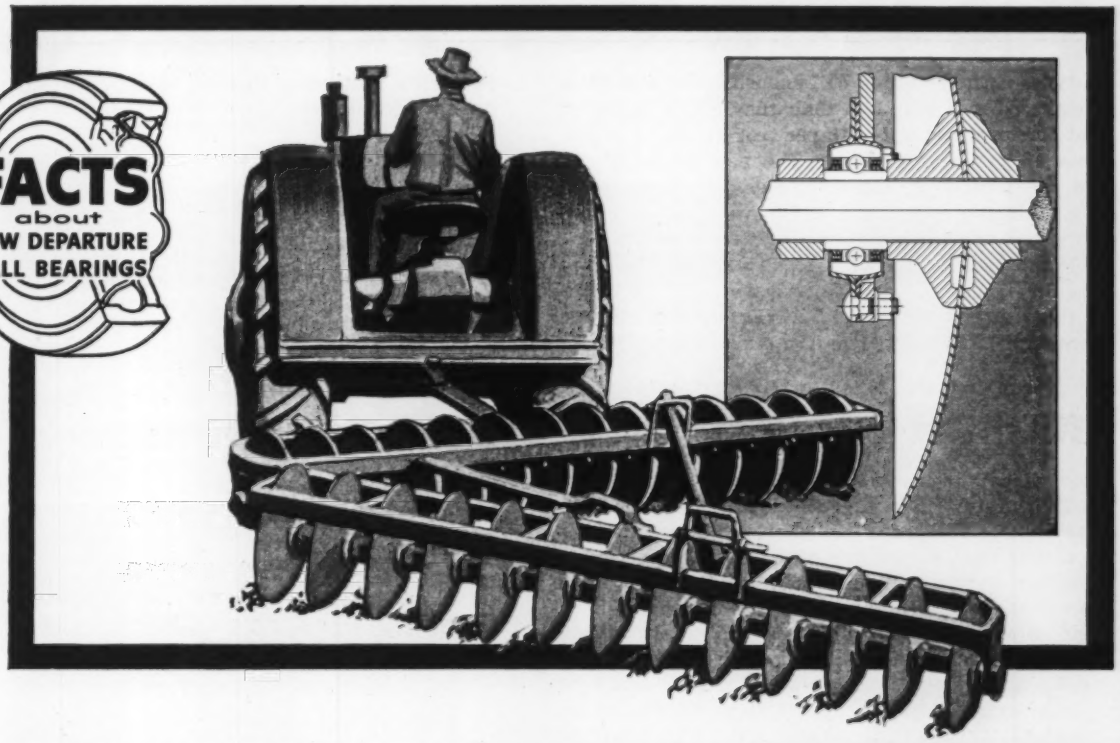
Type	OHV, Vee
No. cyls.	8
Bore & stroke (in)	4.0 x 3.625
Displ. (cu in.)	365
Comp. ratio	10 to 1
Bhp, max	300 @ 4800*
Torque, max (lb-ft)	400 @ 2800

*325 hp available in Eldorado models.

Size and Weight

	Series 62	Series 60	Series 75
Wheelbase (in.)	129.5	133	149.75
Length (in.)	215.9*	224.4	236.2
Width (in.)	80	80	80
Height (in.)	59.1*	59.1	61.6
Weight (lb)	4594*	4755	....

* Four-door sedan.



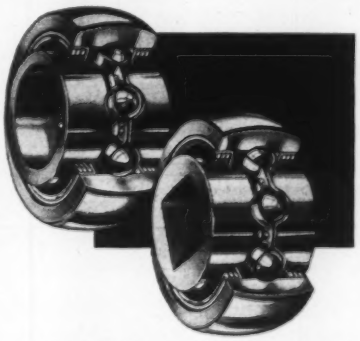
FOUR-YEAR FIELD TEST PROVES DEPENDABILITY OF NEW DEPARTURE DISC HARROW BEARINGS!

No failures in more than four years of tests!

Here's proven dependability with a bonus! For this performance by New Departure heavy-duty disc harrow bearings includes the economy of virtually zero maintenance. With efficient triple-lip seal design, lubricant is sealed *in*, dirt, dust, and wear sealed *out*. Extra-heavy rings give maximum shock resistance . . . insure dependable service under severe operating conditions.

Implement manufacturers save, too, with these ball bearings . . . available in square or round bore. Simple, inexpensive mounting eliminates the need for expensive component parts.

Use the handy dimension chart below for more information about New Departure farm implement bearings. Or, write direct for full details to New Departure, Division of General Motors, Bristol, Connecticut.



Available in square or round bore with spherical O.D., for flange mounting. Also with cylindrical O.D., for "TRUNNION" hanger mount.

PRINCIPAL DIMENSIONS FOR TYPE III BEARINGS

Bearing No.	Shaft Size	Out. Dia.	Width		Stamped Flange No.
Sealed	Nominal	Spherical	Inner	Outer	
AS4508FC	⅞" Square	3.438	1.688	1.312	FL87
AS4508AC	1" Square	3.438	1.688	1.312	FL87
AS4508BC	1⅛" Square	3.438	1.688	1.312	FL87
AS4511AC	1½" Square	4.125	1.750	1.438	FL105*
AS4508DC	1⅛" Round	3.438	1.688	1.312	FL87
AS4509BC	1¾" Round	3.438	1.688	1.312	FL87

*See New Departure representative for availability.

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SUNDAYS—NBC-TV

NEW DEPARTURE
BALL BEARINGS

GM GENERAL MOTORS

NOTHING ROLLS LIKE A BALL

Circle 509 on page 19

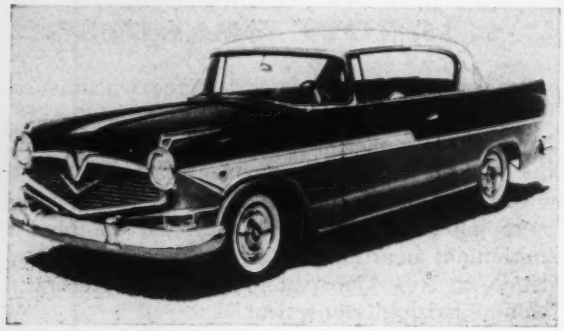
X-type. On the series 75 Limousine, the new frame weighs 3.5 per cent less than the 1956 counterpart, but torsional rigidity is 18 per cent greater and stiffness 16 per cent greater. The new frame is considered particularly suited for four-door hardtop styling. All four-door bodies except the Limousine have only two side windows and no center posts.

Front suspension is spherical joint type with braking dive control. Rear suspension uses semielliptical springs moved outward, closer to the wheels than formerly. Front and rear tread are both 61 in.

HUDSON

Styling refinements and a new V-8 engine rated at 255 hp are features of the Hudson line for 1957. The Hornet V-8 series is available in super and custom four-door sedans and two-door hardtop models. Exterior finishes include 15 solid colors, 12 two-tone combinations and 5 three-tone styles. The V-8 engine is equipped with a four-barrel carburetor and dual exhausts as standard equipment. Ease of accessibility and servicing were objectives in its design.

The engine is available with three transmissions: standard synchromesh, optional automatic overdrive, and optional "Flashaway" Hydra-Matic. Improve-



ments in the "Flashaway" automatic transmission are intended to provide smooth and silent shifting in all ranges. A new "Park" position has been added for safety in parking.

Equipped with 14-in. wheels, the 1957 Hudsons are 2 in. lower than 1956 models. For passenger safety, Hudson bodies and frames are welded as a single unit. Kingpin type front suspension has been replaced by a steering knuckle assembly which pivots on antifriction bearings.

Engine Specifications

Type	OHV, Vee
No. cyls.	8
Bore & stroke (in)	4 x 3¼
Displ. (cu in.)	327
Comp. ratio	9.0 to 1
Bhp, max	255 @ 4700
Torque, max (lb-ft)	345 @ 2600

Size and Weight

Wheelbase (in.)	121¼
Length (in.)	209¼
Width (in.)	78
Height (in.)	60⅜
Weight (lb)	3600*

*Unofficial, for four-door sedan.

STUDEBAKER

The Studebaker line is composed of 11 sedans and four station wagons in three series. A four-door station wagon is available for the first time.

Introduced with the 1957 models are variable-rate coil springing and a Twin-Traction axle with nonslip power-dividing differential. The new type of suspension adjusts automatically to varying loads throughout the spring range. The safety differential automatically divides power between the rear wheels to compensate for lack of traction in one. Up to 80 per cent of driving force can be transmitted to one wheel.

Overdrive and Flightomatic transmissions are

Engine Specifications

	Champion Series; Silver Hawk 6	Commander Series
Type	L-head, In-Line	OHV, Vee
No. cyls.	6	8
Bore & stroke (in.)	3 x 4⅜	3 9/16 x 3¼
Displ. (cu in.)	185.6	259.2
Comp. ratio	7.8 to 1	8.3 to 1
Bhp, max	101 @ 4000	180 @ 4500*
Torque, max (lb-ft)	152 @ 1800	260 @ 2800
	President Series; Silver Hawk V8	**Golden Hawk**
Type	OHV, Vee	OHV, Vee
No. cyls.	8	8
Bore & stroke (in.)	3 9/16 x 3⅜	3 9/16 x 3⅜
Displ. (cu in.)	289	289
Comp. ratio	8.3 to 1	7.8 to 1
Bhp, max	210 @ 4500†	275
Torque, max (lb-ft)	300 @ 2800	333 @ 3200

*195 @ 4500 with optional 4-barrel carburetor.
†225 @ 4500 with optional 4-barrel carburetor.

Size and Weight

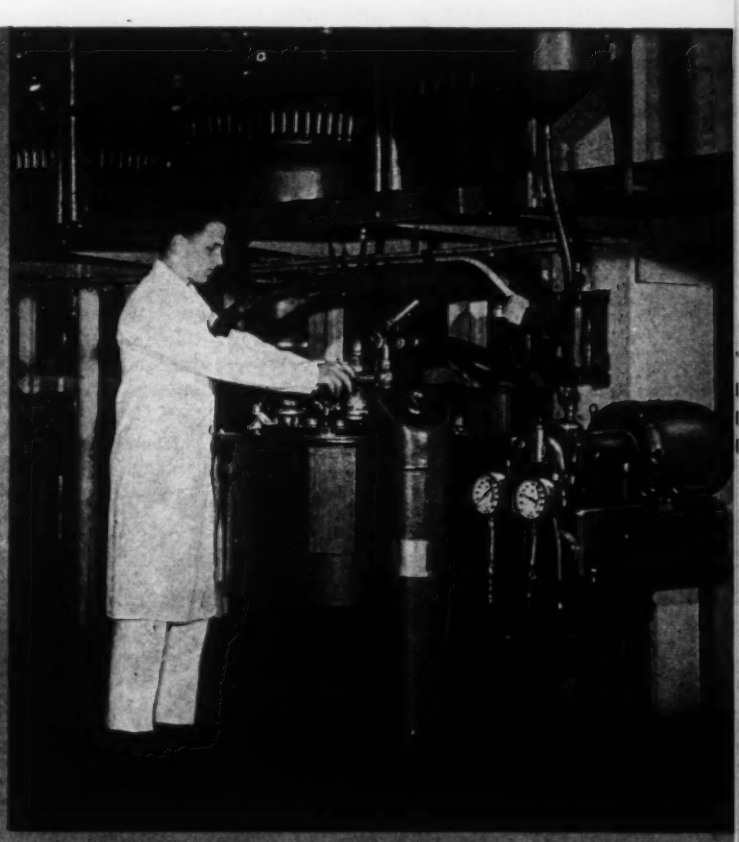
	President, Commander and Champion Series	President Classic	Hawk Series
Wheelbase (in.)	116½	120½	120½
Length (in.)	202⅜	206⅜	203 13/16
Width (in.)	75.8	75.8	71.3
Height (in.)	60*	60.4	57½†
Weight (in.)	3205	3270	3400

*President 4-door sedan.
†Golden Hawk model.

Any speed for you too!

Unique Oilgear Fluid Power "ANY-SPEED" Drives establish new production and economy records

Any desired speed from zero to maximum . . . any rate of acceleration . . . any rate of deceleration . . . any rate of hydrodynamic braking . . . any speed adjustment between operations . . . synchronization of two or more drives . . . direct or remote precision speed control irrespective of load, input power or oil viscosity changes . . . all with Oilgear Fluid Power "Any-Speed" Drives. Old and new users name them *"the drives"* for their heavy-duty needs. You probably didn't know this! Every day, people are equally surprised—*and far more amazed when they know the facts.* Write and get them *now.* THE OILGEAR COMPANY, 1568 W. Pierce Street, Milwaukee 4, Wisconsin.



This Centrifuge at Abbott Laboratories

Leading house in pharmaceutical, drug and chemical field, Abbott Laboratories installed first Oilgear Drive on Tolhurst centrifuge in production department. Experience was so satisfactory it led to the inclusion of another Oilgear equipped Tolhurst centrifuge in their experimental laboratories.

SPECIFICATIONS: Speed continuously variable from zero to 1200 rpm max. (in this case). Full control of acceleration/deceleration speed and rate. Permits that infinitely modifiable speed best suited to loading, washing, spinning and unloading.

Photo Courtesy, Chemical Processing Magazine

This Centrifuge at powder plant in east

In a somewhat different application, these 4 Oilgear 60 hp "Any-Speed" Drives serve Tolhurst centrifuges in powder plant in the east. Centrifuge accelerates to 300 rpm for loading, to 900 rpm for 15-minute centrifuging, then decelerates to 70 rpm for "plowing." Unloading is automatic.

Tolhurst is a division of American Machine & Metals, Inc.

OILGEAR
Fluid Power

PIONEERS . . . NOW THREE PLANTS FOR FLUID POWER

Circle 510 on page 19

PUMPS, MOTORS, TRANSMISSIONS, CYLINDERS AND VALVES

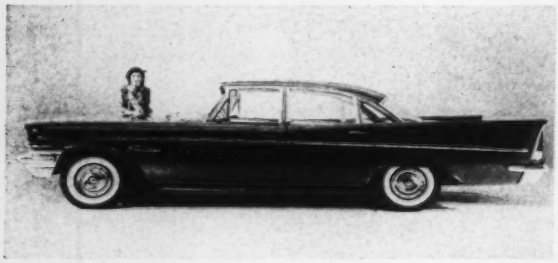
optional on all models. Finned brake drums increase cooling area 100 per cent over previous types. Wheels are 15-in. diam.

Five-passenger, sport-type models in the Hawk series are styled with outward-canted rear fins and a radiator-type grille. They are several inches lower than other Studebaker models. Standard equipment on the Golden Hawk is a supercharger, a 5-lb, full-pressure system that supplies 30 per cent more fuel and air mixture to the combustion chamber than would customary piston action.

CHRYSLER

A new Saratoga series has been added to the New Yorker and Windsor series in the Chrysler line for 1957. Saratogas are made in a four-door sedan and two and four-door hardtop models. Nine other models are in the line.

The cars have Chrysler's new Torsion-Aire suspension system, in which torsion bars replace coil springs



in the front end. Lower control arms, ball joints, rubber isolators and a new front sway bar minimize brake dip. Brakes are total-contact, center-plane type. Low-pressure, 14-in. tires are standard; Captive-Air tires are optional on station wagons.

Other innovations are optional twin headlights, up to 40 per cent greater windshield area, recessed door handles, anodized aluminum grilles, and a combination heater-air conditioner. In the twin headlight set-up, the two outside lamps have filaments for high and low beam; inner lamps have high beam only.

Engine Specifications

	Windsor	Saratoga	New Yorker
Type	OHV, Vee	OHV, Vee	OHV, Vee
No. cyls	8	8	8
Bore & stroke (in.)	3.94 x 3.63	3.94 x 3.63	4.0 x 3.9
Displ. (cu in.)	354	354	392
Comp. ratio	9.25 to 1	9.25 to 1	9.25 to 1
Bhp, max	285	295	325
Torque, max (lb-ft)	365 @ 2400	390 @ 2800	430 @ 2800

Size and Weight

	Windsor	Saratoga	New Yorker
Wheelbase (in.)	126	126	126
Length (in.)	219.2	219.2	219.2
Width (in.)	78.8	78.8	78.8
Height (in.)	57.2	57.0	57.0
Weight (lb)*	3995	4165	4315

*Four-door sedans.

Horsepower in Chrysler's V-8 engines is higher than in last year's models. Three-speed pushbutton Torque-Flite transmission is standard on New Yorker and Saratoga models, optional on Windsors. The pushbutton for neutral also serves as the starter button, automatically placing the car in neutral when it is started.

PONTIAC

Three series of Pontiacs in 16 body styles and on two wheelbases make up the 1957 line. Overall length has been increased 1.2 in., and the cars are lower. Wheels are 14-in. diam. Finished with new "Lucite lacquer," the cars are available in 12 solid colors and 56 two-tone combinations.

Wrap-around front bumpers are made with set-in oval parking lights. Rear bumpers contain dual exhaust ports. An air scoop the width of the grille supplies air for cooling the radiator. Windshield area has been increased as much as 75.4 sq in. A foot-operated parking brake replaces the previous hand-brake.

The 1957 V-8 engine has increased horsepower and higher compression ratio than last year's. Intake valve stems are vented to atmospheric pressure to

Engine Specifications

	Chieftain Series	Super Chief and Star Chief series
Type	OHV, Vee	OHV, Vee
No. cyls.	8	8
Bore & stroke (in.)	3.94 x 3.56	3.94 x 3.56
Displ. (cu in.)	347	347
Comp. ratio	8.5 to 1	10.25 to 1
Bhp, max	227 @ 4600; 252 @ 4600*	....
Torque, max (lb-ft)	333 @ 2300; 354 @ 2400*	....

*Hydra-Matic transmission engines.

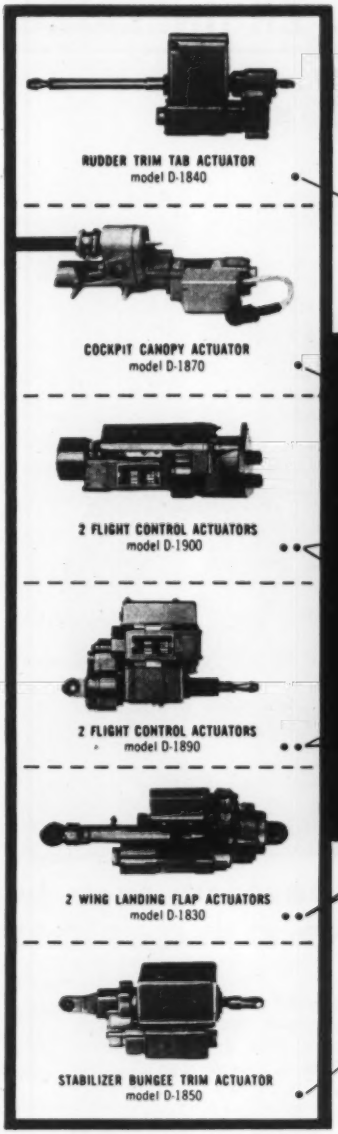
Size and Weight

	Chieftain, Super Chief, Star Chief Station Wagon	Star Chief Deluxe and Custom
Wheelbase (in.)	122.0	124.0
Length (in.)	206.8	213.8
Width (in.)	75.2	75.2
Height (in.)	60	60
Weight (lb)	3560	3630

prevent oil from being drawn into the combustion chambers under high-vacuum operating conditions. Piston stroke has been increased from 3¼ to 3 9/16 in. by means of a new crankshaft design. A new

(*Continued on Page 22*)

9 HOOVER ACTUATORS
flex the muscles of the Navy's New Fury Jet



North American FJ-4 Fury. Now in production at North American's Columbus, Ohio division for the Navy, this carrier-based, swept-wing jet fighter has a high rate of climb and speed in excess of 690 mph.

Hidden under the skin of North American's new FJ-4 Fury jet are nine custom-built Hoover Electric actuators that provide precise, dependable power and control—for flying the Navy's latest Super Jet.

Exactingly designed—and precisely built—for maximum performance under all conditions—these Hoover-built electric power control units have been an integral contribution to American aircraft development for more than a decade. Aircraft designers, engineers and pilots alike—rely on Hoover dependability—and Hoover has always repaid that confidence with Performance PLUS!

Hoover Electric will design and manufacture special actuators and motors, special gearing and complete power package units for any application—in experimental or production quantities. Write today!

Hoover Electric Motors And Actuators Are Providing Dependable Power And Control For Operating

horizontal stabilizers	camera doors
camera drive	fuel jettison actuator
ram air inlet	cockpit canopy
landing hook	pilot seat actuators
aileron control	hydraulic pump
hot air valve	high pressure air pumps

HELCO

HOOVER ELECTRIC COMPANY

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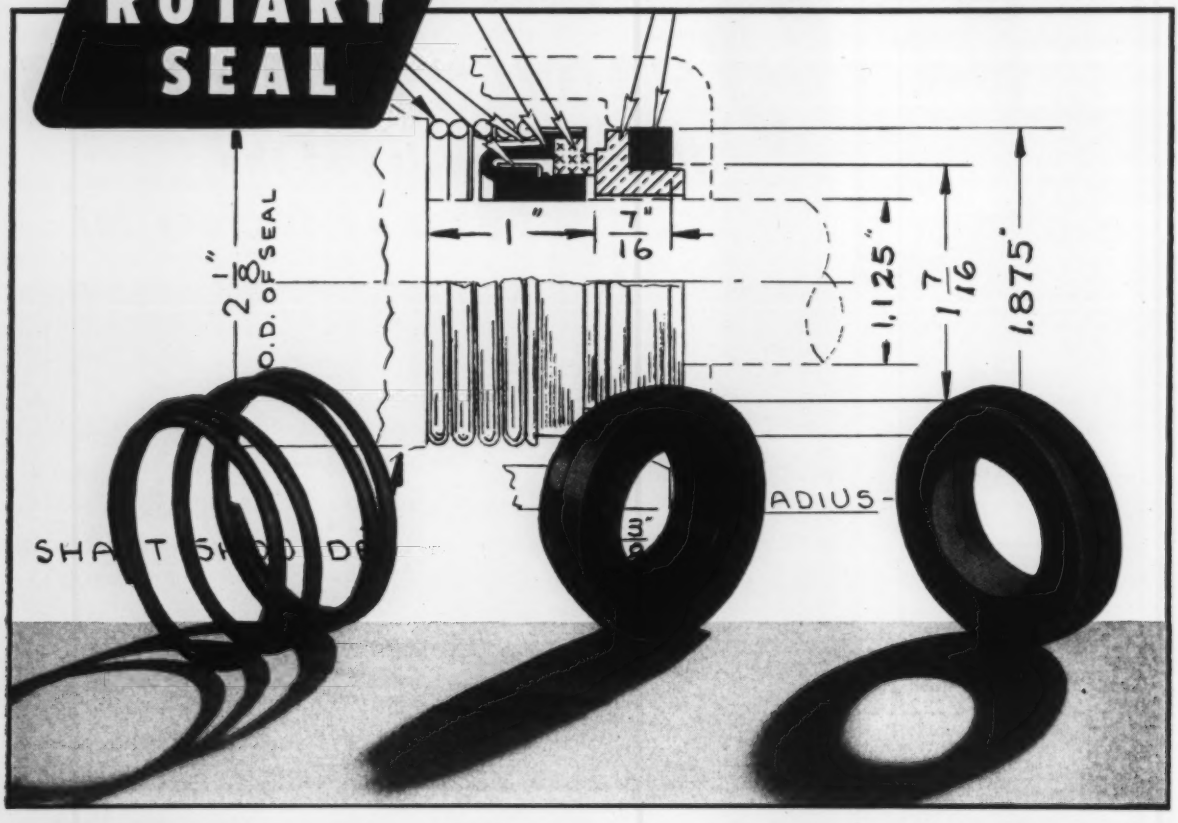
Circle 511 on page 19

ROTARY SEAL

SPECIALIZED SEAL ENGINEERING



is developing new ways to assure top performance in DIFFICULT HEAVY-DUTY SEWAGE PUMP OPERATION

There are all sorts of pumps, for all sorts of purposes, and Rotary Seals of varying designs are in wide use along the whole range. But here's an application where the pump operates under some of the most extreme conditions you can imagine—in a heavy-duty sewage system. Often, the pump is completely drowned while working; and the kind of flowage it must handle offers difficulties of its own.

The Shaft Seal—at the operating heart of the pump—must obviously be built to "take it"—and keep on taking it, because constant maintenance or repairs are inconceivable under the circumstances. And, as so often is the case when the assignment is tough, it's a Rotary Seal *(custom-designed* to meet the unusual conditions) which is doing the job. That's our business: solving hard Shaft Sealing problems by applying the basic Rotary Seal principles which opened the way to successful mechanical Shaft Sealing when this company introduced them years ago.

Major assignments for important Seal developments are keeping us mighty busy at present; but if special difficulties are besetting your development programs, and production quantities of Seals are involved, we'll be glad to help if we can.

THE ROTARY SEAL Division of MUSKEGON PISTON RING CO.

mechanical seals for rotating shafts

Shaft-Sealing with Certainty

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Reader Information Service

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USE A YELLOW CARD
for More Information . . .

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EDITORIAL CLIPSHEETS—So you won't have to "clip" this issue, we'll be glad to send a personal copy of any article as long as the supply lasts. Just fill in the page number and title of article in the place provided on the Yellow Card.

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BY ITEM NUMBERS

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CLEVELAND, OHIO

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No Postage Stamp Necessary if Mailed in the United States

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Penton Building
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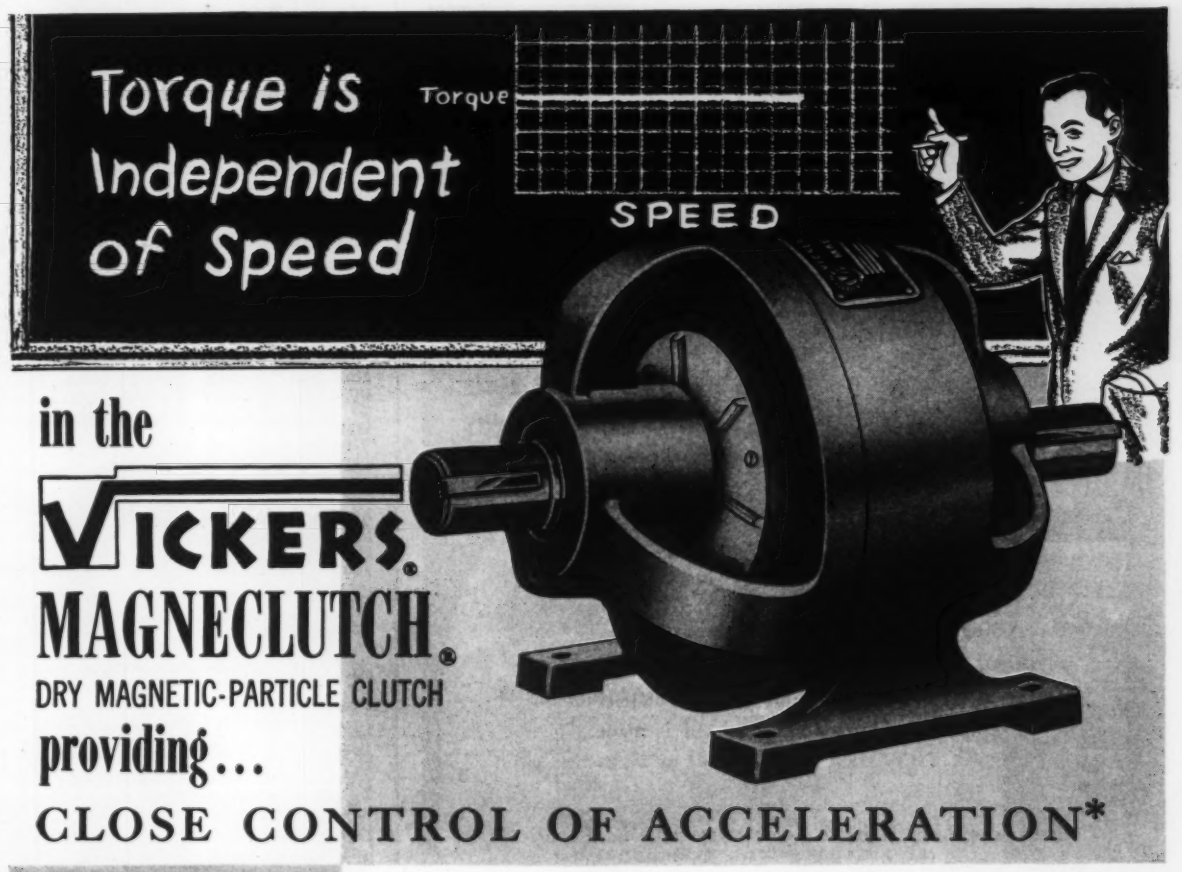
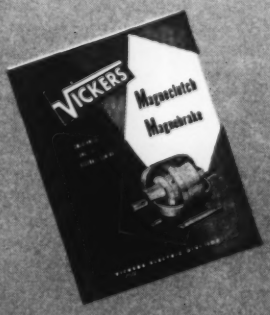


in the VICKERS® MAGNECLUTCH®

DRY MAGNETIC-PARTICLE CLUTCH

providing...

CLOSE CONTROL OF ACCELERATION*



Vickers MAGNECLUTCH may also be used for braking and tension control. Get the complete facts. Write today for bulletin and application data forms.

IN the Vickers MAGNECLUTCH, torque is transmitted through the linking action of magnetized ferromagnetic particles in the gap between driving and driven members. The amount of torque transmitted is regulated by varying the amount of energizing current, and is independent of the rotational speed of the driving and driven members. This torque transmission principle permits extremely close control of acceleration.

VICKERS MAGNECLUTCH

Also Offers These Other Outstanding Advantages

SMOOTH OPERATION
LONG LIFE, *because there's no wear on torque transmitting surfaces*
TORQUE AT ZERO SLIP—*torque transmitted with 100% mechanical efficiency*
EXTREMELY FAST RESPONSE
SMALL CONTROL POWER
EASILY ADAPTED TO REMOTE CONTROL

*Equally close control of deceleration may be obtained with Vickers MAGNEBRAKES.

VICKERS ELECTRIC DIVISION

VICKERS INCORPORATED a unit of Sperry Rand Corporation

1881 LOCUST STREET • SAINT LOUIS 3, MISSOURI

Circle 513 on page 19

Research Supplies the Right Combination . . .

Chief Sandusky

FERROUS AND NON-FERROUS CENTRIFUGALLY CAST ROLLS, SLEEVES, TUBES, LINERS, CHUTES, RETORTS, RINGS, BUSHINGS, BEARINGS, ETC.

A centrifugal casting that will successfully resist heat, corrosion, or abrasion is no "hit or miss" proposition. It's the direct result of a combination of important factors determined before the casting itself is made.

That's where our research department steps in. Experienced technicians work in direct conjunction with your specific problems or needs. They make sure your ferrous and non-ferrous cylindrical castings get the proper start. Quality control, from raw material through final inspection, checks all remaining factors. Machining facilities for turning, boring, and drilling is an additional service.

If you're not sure of the right combination for your present or proposed needs, our technical aid is immediately available to you.

C. M. Lovsted & Co., Seattle, Wash. • Tynes Bros., Birmingham, Ala. • Cordes Bros., San Francisco and Wilmington, Calif.

Chief SANDUSKY CENTRIFUGAL CASTINGS

FERROUS AND NON-FERROUS

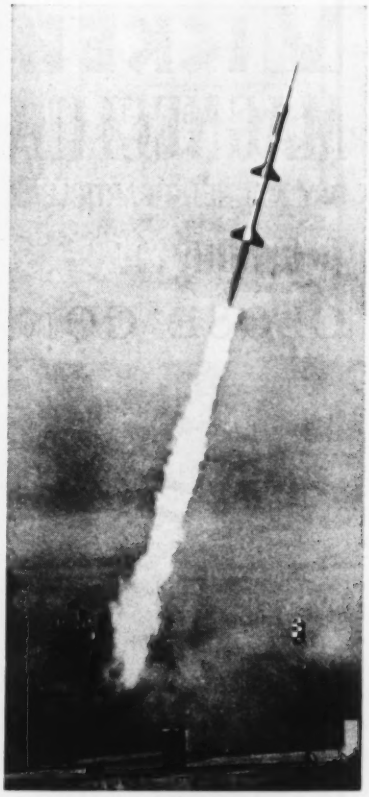
SANDUSKY FOUNDRY AND MACHINE CO., Sandusky, Ohio

News Roundup

(*Continued from Page* 14)

cylinder head includes a completely machined, contoured combustion chamber with steamlined passages leading to the combustion chamber for better fuel flow. Intake and exhaust ports, as well as intake and exhaust manifolds, have been enlarged. Carburetor include larger venturis with larger throttle bores.

MACHINE DESIGN's roundup of the 1957 model automobiles will be continued in the December 13 issue.



ONE MILLION FEET was the altitude reached by this four-stage research missile fired recently by NACA scientists at the Pilotless Aircraft Research Station, Wallops Island, Va. Maximum speed was 6600 mph. The first two motors were the type used on the Nike missile. These and the third stage fell free when spent. The fourth was part of the missile itself. Purpose of the flight, which ended in the Atlantic Ocean, was to obtain high altitude research information.

Eventual Economies Seen In Atom-Powered Merchant Ships

WASHINGTON, D.C.—Considerations which have led to approval of construction of the first nuclear powered merchant ship were stated recently by Louis H. Roddis, deputy director, Division of Reactor Development, U. S. Atomic Energy Commission. Mr. Roddis gave three main reasons for the venture.

"The principal reason is that the application of nuclear power to merchant ships is . . . economically promising. Secondly, it would contribute to national security by providing a measure of independence from foreign fuel sources. Finally, it will contribute to world-wide economic development by conserving the limited world supply of fossil fuels."

The first ship will probably not earn its cost, due to its experimental nature, but Mr. Roddis said future ships should be economical to operate. He gave these reasons:

"Capital costs of shipboard nuclear powered plants in the range of 15,000 to 20,000 shaft hp should not be significantly more than land based reactors of similar concept. In fact, the ability to construct and test these plants in well-equipped and completely staffed yards may give the ship application an advantage.

"Nuclear ships should be able to achieve greater gross revenue than conventional ships of similar displacement, for several reasons:

"On any long voyage nuclear ships will be able to carry a larger cargo because the nuclear reactor will require less space than the conventional equipment plus its fuel oil.

"Nuclear ships will be able to operate on longer runs at higher sustained speeds.

"They will be able to achieve quicker turn-around in port because . . . refueling will be avoided.

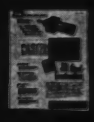
"They will be more flexible in the routes they can travel because they will not be dependent on more than one home port for refueling purposes.

"While initially the fuel costs for nuclear ships will be about $0.70 per million Btu as compared to average fuel oil costs of about $0.35 per million Btu at this time, we believe that these higher oper-

HERE'S WHY CARTER CAN OFFER
IMMEDIATE DELIVERY
ANY BORE SIZE • ANY MOUNT • ANY STROKE
CYLINDERS
AIR OR HYDRAULIC

AIR CYLINDERS

250 LB. HYDRAULIC


CLAMP CYLINDERS

1500 LB. HYDRAULIC

AIR VALVES

BUILT-IN VALVE TYPES

- **100% EXPANSION OF FACILITIES**
  Carter is geared to give service. We have increased our plant capacity to handle orders on an IMMEDIATE DELIVERY basis.
- **THE EXCLUSIVE CARTER DESIGN**
  Carter cylinders are designed for fast production and immediate off-shelf assembly from standard parts.
- **THREE SHIFT OPERATION**
  Carter produces around the clock. Your order for cylinders is in process *in a matter of minutes* after we receive it.
- **SPARE PARTS AND SERVICE**
  Carter maintains complete spare parts and experienced engineers in 40 different locations throughout the United States, Canada, and Mexico.
- **PHONE 24 HOURS A DAY**
  Call in your order any time of the day or night. Carter will take your order and begin processing it right away.

If you need cylinders fast, try us today.

Phone Lansing, Illinois, GRanite 4-3305
or Chicago, BAyport 1-7186

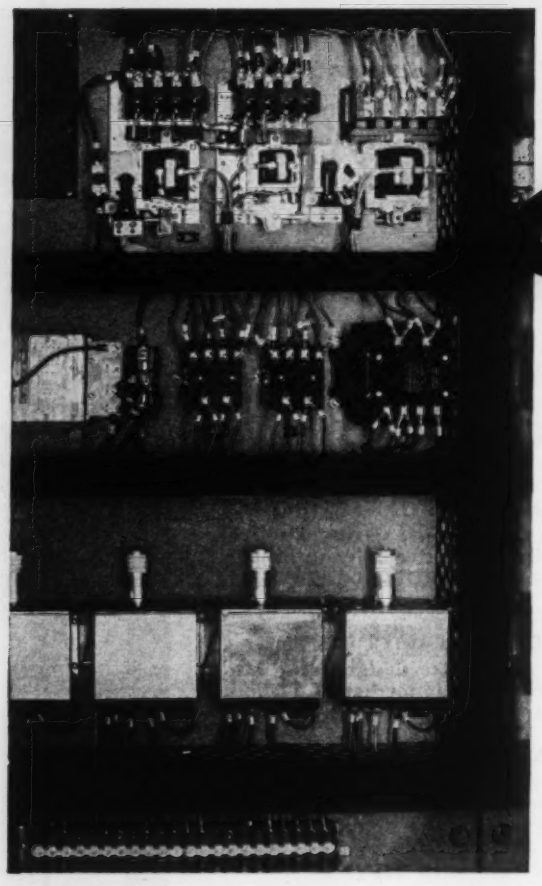
SEND FOR COMPLETE CATALOG FILE!
All the details you need for ordering Carter Cylinders and Controls of any kind. Complete with spare parts data, specifications and prices.

CARTER CONTROLS INCORPORATED
2914 Bernice Road • Lansing, Illinois (Chicago Suburb)
AIR CYLINDERS • AIR VALVES • HYDRAULIC CYLINDERS
ROTARY ACTUATORS • SPECIAL CONTROLS

Circle 515 on page 19

New GLASTIC "CHANNEL-DUCT"

Cuts Control Panel Wiring Costs 30%



OTHER ADVANTAGES TOO!

Flexible wire is laid in duct and strung through holes to terminal connections. Duct is formed from two perforated side strips and solid covering of Glastic, all held in place with clips screwed to panel. Covering strip is snapped on.

Does complex wiring run up your assembly costs? Do hand-formed solid wire layouts present a serious time problem? . . . Glastic's *new* Channel-Duct material, holding control panel wiring in place, has slashed manufacturing costs by 30% . . . makes installation changes easy . . . has superior dielectric and flame-resistant properties . . . resists warpage during and after assembly . . . eliminates expensive harnesses . . . avoids fractures . . . simplifies maintenance . . . improves the product.

Your letterhead request will bring Bulletin GG-3

The GLASTIC Corporation
4325 Glenridge Road
Cleveland 21, Ohio

GLASTIC
GLASS REINFORCED PLASTIC
T. M.

"Class B Insulation at Class A Prices"

("Glastic" is a registered trade mark for products of The Glastic Corp.)

ating costs will be more than offset by the increases in gross revenue."

Mr. Roddis also gave reasons for an early start on nuclear ship propulsion. "There is in prospect a widespread replacement, expansion, and modernization of merchant fleets throughout the world. We are told that as of December 31, 1955, there were 1762 ocean-going merchant ships of 1000 gross tons and over under construction or on order. Another estimate is that an average of 300 tankers per year will be constructed in the next years, many of them super-tankers.

"The first ship will be designed and built to meet many of the requirements of a commercial ship. It will, however, be put together in such a way that improvements can be made in it from time to time."

Meetings

AND EXPOSITIONS

Dec. 9-12—
American Institute of Chemical Engineers. Annual Meeting to be held at Hotel Statler, Boston. Further information can be obtained from the institute's headquarters, 25 W. 45th St., New York 36, N.Y.

Dec. 9-12—
American Society of Agricultural Engineers winter meeting to be held at the Edgewater Beach Hotel, Chicago. Further information can be obtained from society headquarters, 420 Main St., St. Joseph, Mich.

Dec. 10-11—
Material Handling Institute Inc. Annual Meeting to be held at the Biltmore Hotel, New York. Further information can be obtained from institute headquarters, Suite 759, 1 Gateway Center, Pittsburgh 22, Pa.

Dec. 10-12—
1956 Eastern Joint Computer

Conference to be held at the Hotel New Yorker. Sponsors are the Institute of Radio Engineers, American Institute of Electrical Engineers and the Association for Computing Machinery. Additional information is available from publicity chairman Albert J. Forman, Tele-Tech & Electronic Industries, 480 Lexington Ave., New York 17, N. Y.

Jan. 14-16—

Third National Symposium on Reliability and Quality Control in Electronics to be held at the Hotel Statler, Washington, D. C. Sponsors are Institute of Radio Engineers, American Society for Quality Control, American Institute of Electrical Engineers and Radio-Electronic-Television Manufacturers Association. Further data are available from Mr. R. G. Murrell, Melpar Inc., Falls Church, Va.

Jan. 14-18—

Society of Automotive Engineers Inc. Annual Metting to be held at the Sheraton-Cadillac and Statler Hotels, Detroit. Further information can be obtained from society headquarters, 485 Lexington Ave., New York 17, N. Y.

Jan. 16-18—

Society of Plastics Engineers Inc. Thirteenth Annual National Technical Conference to be held at the Hotel Sheraton-Jefferson, St. Louis. Further information can be obtained from society headquarters, 34 E. Putnam Ave., Greenwich, Conn.

Jan. 21-25—

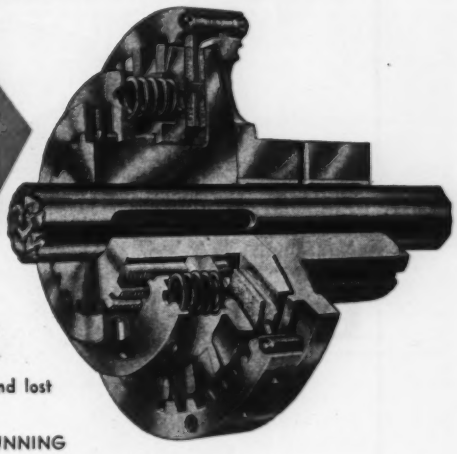
American Institute of Electrical Engineers. Winter General Meeting to be held at the Hotel Statler, New York. Further information is available from AIEE headquarters, 33 W. 39th St., New York 18, N. Y.

Jan. 28-31—

Plant Maintenance and Engineering Show to be held at the Cleveland Public Auditorium. Further information can be obtained from Clapp & Poliak Inc., 341 Madison Ave., New York 17, N. Y.

HILLIARD *Clutches*
FOR POWER CONTROL DESIGN

ADJUSTABLE
Slip Clutch



- PROTECTS against overload, jams and down time.
- RESUMES THE DRIVE AUTOMATICALLY after overload.
- ELIMINATES SHEAR PINS and lost time.
- ADJUSTABLE - WHILE - RUNNING feature is available.

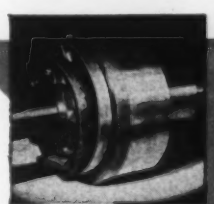
Hilliard Slip Clutches are continuously protecting the drive on dish washing machines—printing presses—packaging machines—case loaders—foundry equipment— air filters—conveyors—overhead doors—and many others.
They maintain steady torque while permitting speed variation on fabric drying drums, steel strip slitters and similar equipment.

The adjustable-while-running types are used to maintain constant tension on rewind stands for paper coaters, textile machines, rope, steel and wire mills and for drive systems requiring overload protection but which must be disconnected at times.

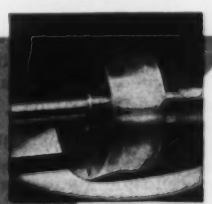
WRITE TODAY FOR BULLETIN 300 WITH COMPLETE INFORMATION.

● OTHER HILLIARD CLUTCHES ●

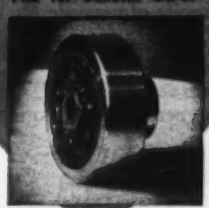
CONSIDER AUTOMATION - INVESTIGATE THESE PRODUCTS



HILLIARD - TWIFLEX CENTRIFUGAL COUPLING for smooth, easy starting of any load automatically with overload protection and ability to accommodate shaft misalignment. Ask for Bulletin CE-3.



SINGLE REVOLUTION CLUTCHES for automatic accurate control—electrical or mechanical—of intermittent motion, indexing, cycling and cut-off. Ask for Bulletin 239.



OVER-RUNNING CLUTCHES for automatic instantaneous engagement and release on two speed drives, dual drives and ratchet, or backstop action. Ask for Bulletin 231.

THE HILLIARD *Corporation*
MANUFACTURING CLUTCHES FOR OVER 50 YEARS

103 WEST FOURTH ST., ELMIRA, N. Y.

IN CANADA: UPTON • BRADEEN • JAMES, LTD.

Circle 517 on page 19

for **HIGH STYLING**

. . . or

HEAVY DUTY

DUREZ

. offers industrial designers almost unlimited scope

● One manufacturer wanted fresh new contours, interesting color, permanence of finish, strength, heat-resistance . . . and economy. The other wanted intricate shapes with holes, grooves, and slots molded-in, self-insulation, rigidity, close tolerances . . . and economy.

Requirements of both are being met in all respects—including production economy—with materials selected from the six classes that constitute the Durez family of versatile molding materials.

Being phenolics, these thermosetting plastics are true engineering materials with an unsurpassed range of industrial applications. You can use their mechanical, electrical, thermal, and chemical properties in creating products that look better, serve better, sell better.

Call on your molder—or our Technical Field Service—for help in solving your problems.

DUREZ® *Phenolic Plastics that fit the job*

DUREZ PLASTICS DIVISION
HOOKER ELECTROCHEMICAL COMPANY
511 Walck Road, North Tonawanda, N. Y.

HOOKER CHEMICALS PLASTICS

MEN

OF MACHINES

Howard J. Seel has been appointed chief engineer of the Cleveland Div. of Harris-Seybold Co. Formerly chief development engineer for sheet-fed offset printing presses, Mr. Seel will now be responsible

Howard J. Seel

for product development, engineering, and final testing. He has been with Harris-Seybold since 1936. Mr. Seel is a member of the planning committee for the Mechanisms Conference held annually under the sponsorship of Purdue University and MACHINE DESIGN.

Ralph S. White was recently appointed manager of research and engineering by the Spinco Div. of Beckman Instruments Inc. in Belmont, Calif. Mr. White has been associated with Beckman for six years, most recently as assistant manager of the Liston-Becker plant of the Scientific Instruments Div. in Stamford, Conn.

Louis C. Lundstrom has been named director of General Motors Proving Grounds, which include facilities at Milford, Mich.; Mesa, Ariz.; and Manitou Springs, Colo. Mr. Lundstrom joined the Proving Ground Staff at Milford as a test

Circle 518 on page 19

engineer in 1939. He was promoted to project engineer in 1942, mechanical department head in 1947 and assistant to the director of the Proving Grounds in 1953. Mr. Lundstrom succeeds **Harold H. Barnes,** who is retiring after 37 years with General Motors.

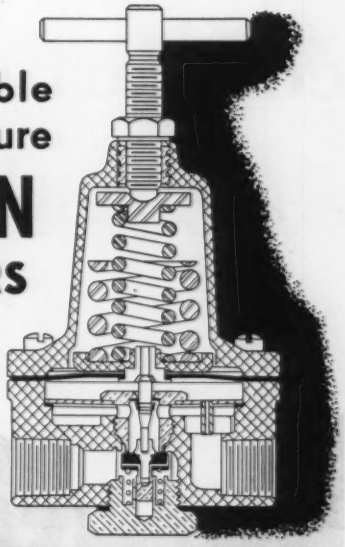
Brown & Sharpe Mfg. Co., Providence, R. I., recently named **Wallace B. Bainton** vice president and general manager for machine tools. Mr. Bainton was vice president for production and engineering. At the same time, **Harold Sizer** was made director of design.

Thomas E. Rounds has been appointed vice president of the Barden Corp., Danbury, Conn. He joined the company as executive engineer in 1943 and became chief engineer in 1947. For five years prior to joining Barden, Mr. Rounds had been assistant chief

Thomas E. Rounds

engineer of Norma-Hoffman Bearings Corp. and was a member of that company's engineering department from 1930 to 1938. He had also worked in the engineering department of SKF Industries Inc. for four years. Mr. Rounds is secretary of the American Ordnance Association's committee on instrument precision ball bearings. He has written numerous articles for MACHINE DESIGN, the most recent of which were on "High-Performance Ball Bearings" and appeared

Accurate, Dependable Control of Air Pressure *with* NORGREN REGULATORS



OVER 400 STANDARD MODELS

Pressures in excess of manufacturer's recommendations result in greater wear, more down-time and higher maintenance cost without significant increase in output. Stop this costly waste. Select a Norgren Regulator that will provide the desired pressure at all times, holding it constant even though the line pressure or rate of flow may vary.

How Norgren Regulators Provide Accurate, Trouble-Free Service . . .

1 **PRESSURE KEPT CONSTANT**
Quick response to sudden demands for greater air volume.

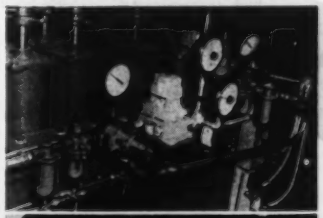
2 **EFFICIENT OPERATION**
Greater air flow with less pressure drop.

3 **PRECISION CONSTRUCTION**
Provides accurate pressure regulation under the most rugged conditions.

4 **RELIEVING FEATURE**
Safeguards connected equipment against damage due to pressure surges.

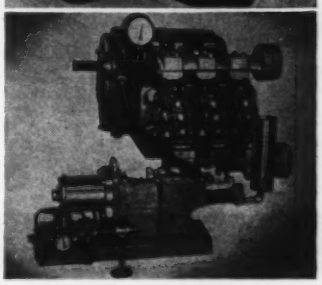
5 **RUGGED DIAPHRAGM**
Made of oil resistant synthetic rubber reinforced with nylon fabric.

6 **EASY TO INSTALL**
Pipe connections are in line.



Sciaky — 16 Year User
Sciaky Bros., Inc., have been using Norgren Regulators on their welders for 16 years because they provide the dependable, accurate air regulation necessary to produce uniform welds of high quality.

Remote Pressure Control for Baldwin-Lima-Hamilton Presses
Because 3 feet of this Baldwin Press is below floor level, including Norgren Pressure Regulators, working air pressure is remotely controlled by Norgren Pilot Regulators —a big sales feature for the press, Baldwin engineers say.



Air-Hydraulic Pressures Balanced for Milton Roy Co.
Norgren Pressure Regulators help provide a closely-controled balance between air pressure and hydraulic pressure for "airROYmetric" Pressure Generators. Every air-powered Milton Roy Pump includes Norgren equipment.

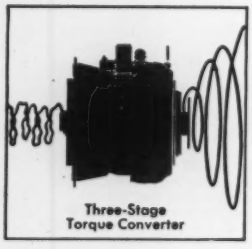
Call your nearby Norgren Representative listed in your telephone directory, or WRITE THE FACTORY FOR NEW CATALOG.

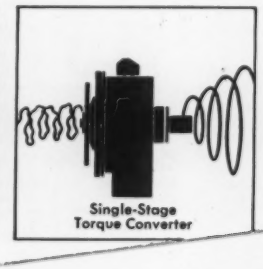
C.A. Norgren CO.
3442 So. Elati St., Englewood, Colo.

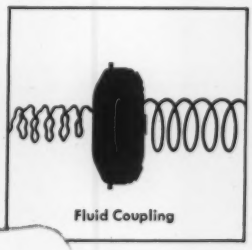
Wherever Air is Used in Industry

Circle 519 on page 19

converter
or coupling?
...for unbiased* recommendations,
consult
Twin Disc!


Three-Stage Torque Converter


Single-Stage Torque Converter


Fluid Coupling

*Unbiased because Twin Disc—the world's largest manufacturer of both fluid and friction drives for industrial powered equipment—offers *a complete line* of fluid drives . . . torque converters (single-stage *or* three-stage) from 30 to 1000 hp . . . fluid couplings from ¾ to 850 hp . . . to meet virtually every heavy-duty requirement for fluid power transmission.

TWIN DISC
CLUTCHES AND HYDRAULIC DRIVES

TWIN DISC
Friction Clutches and Fluid Drives

TWIN DISC CLUTCH COMPANY, Racine, Wisconsin • HYDRAULIC DIVISION, Rockford, Illinois
Branches or Sales Engineering Offices: Cleveland • Dallas • Detroit • Los Angeles • Newark • New Orleans • Tulsa

Men of Machines

in the September 20 and October 18 issues.

Bruce L. Mims, formerly assistant chief engineer, succeeds Mr. Rounds as chief engineer.

Formerly vice president of research, **Irven Travis** has been named vice president of research and engineering by Burroughs Corp., Detroit. **Raymond G. Bower,** former vice president of engineering, has retired.

Walter R. Bush has been appointed vice president in charge of engineering and a member of the Management Committee of Fenwal Inc., Ashland, Mass. He will be responsible for all research and applied engineering work on a variety of products and will also

Walter R. Bush

direct current and contemplated work on a large number of new control developments. Prior to joining Fenwal, Mr. Bush was chief components development engineer for Republic Aviation Corp. He had also served as technical assistant to the chief engineer, and assistant chief research engineer at Republic.

Farnsworth Electronics Co., Fort Wayne, Ind., has appointed **Arthur N. Corner** to the position of project manager, missile test equipment. Mr. Corner was assistant to the president and acting director of engineering at the Electronics

Circle 520 on page 19

Corp. of America. He has also served as general manager of the Arlington Div. of Melpar Inc., as executive engineer with the Kellex Corp., and has been associated with Link Aviation Inc., Glenn L. Martin Co. and McDonnell Aircraft Corp.

J. P. Matthews has been named turbocharger application engineer by the Cooper-Bessemer Corp., Mt. Vernon, O. Mr. Matthews previously was concerned with product improvement and expansion of the company's line of engines and compressors.

Samuel P. Caldwell has been appointed to the newly created position of director of research and development by the Greist Mfg. Co., New Haven, Conn. He has been vice president and assistant general manager of the company's Air-Marine Div. and, except for three years, has been associated with Greist since 1936.

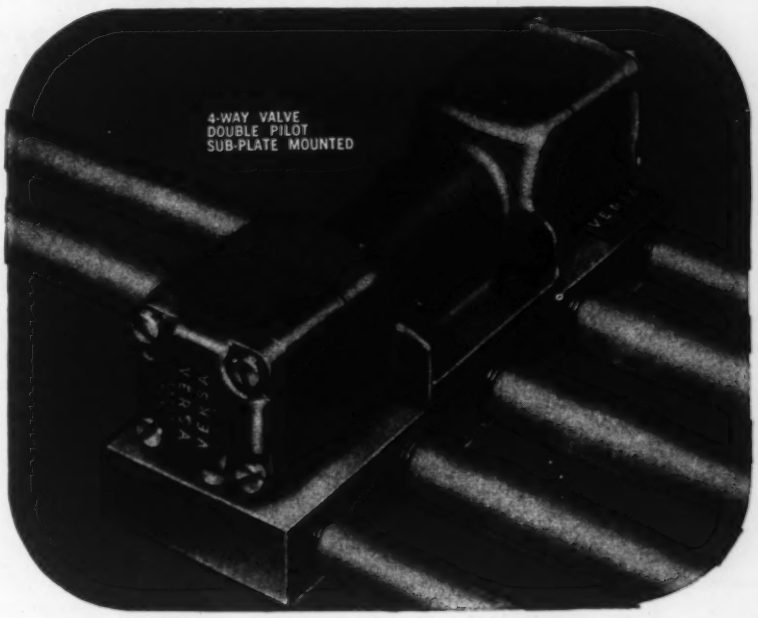
Siegler Corp., Chicago, has announced the election of **John J. Burke** to vice president of engineering of its Hallamore Electronics Co. division.

P. G. Smith has joined Roylyn Inc., Glendale, Calif., as assistant to the president. Mr. Smith had been associated with Douglas Aircraft Co. since 1939. He served as assistant section leader, power plant engineering, before establishing the company's Engineering Labs, which are responsible for developing and testing all systems and components of Douglas airplanes.

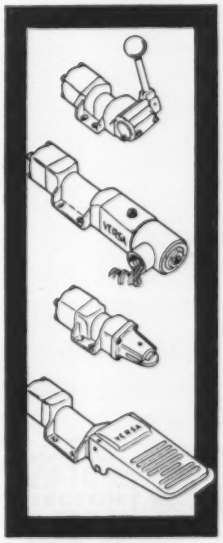
Head of the engineering department since 1945, **George C. Wilsher** was recently made vice president of engineering by Holcroft & Co., Detroit.

Terence Caffrey has been named chief engineer of the air compressor division of Davey Compressor Co., Kent, O. Before joining this company in 1954, he was associated with Alfred Bullows & Sons Co. as a designer of compressors and pneumatic equipment.

FOR MAXIMUM CAPACITY
IN MINIMUM SPACE . . .



THE VERSA
MANIFOLD MOUNT VALVE



The **Versa Manifold Valve** has been especially designed for use where space is at a premium.

All piping can be installed, connected to manifold plate and even purged before installation of the valve itself. The valve is then simply bolted into place on the manifold plate. The valve proper, being independent of the piping, can be easily removed for service or replacement without disconnecting piping or disassembling the valve.

Versa Control Valves are available with any type of actuating device in sizes from ⅛" to 1" NPT, in 2-, 3-, 4-, and 5-way type, and for pressures from partial vacuum to 500 PSIG.

All Versa Valves are triple pressure and functionally tested under water for guaranteed leakproofness.

Over 110,000 Variations . . .
Ready for Immediate Delivery!

VERSA

The entire line of VERSA valves is explained in our new comprehensive Folder #14

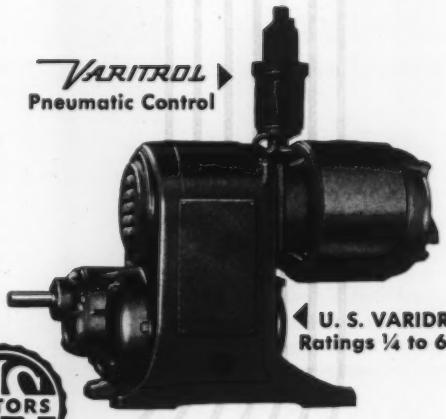
VERSA PRODUCTS COMPANY INC.
247 SCHOLES STREET
BROOKLYN 6, N. Y.

Circle 521 on page 19

HOW VARITROL AUTOMATIC SPEED CONTROL saves Manpower

Human Error is Eliminated with U. S. VARIDRIVE MOTORS WITH VARITROL

Now, by controlling speed with Varitrol as a component of the U.S. Varidrive motor, speeds can be *automatically* changed in response to a signal *without* human attention. Varitrol pneumatic control regulates the speed of Varidrives in response to a signal from such variables as temperature, humidity, pressure, speed, liquid level, weight and tension. Varitrol automatic control of Varidrives offers an opportunity for improved quality of product, greater uniformity and more efficiency in plant flow handling. A profusely illustrated multi-color booklet explaining in detail the construction and operation of Varitrol automatic control is available. Write today for your copy.



U.S. Electrical MOTORS

U. S. ELECTRICAL MOTORS, INC. MD-11
P. O. Box 2058, Los Angeles 54, Calif., or Milford, Conn.
☐ Send Varitrol Automation Booklet No. 1882
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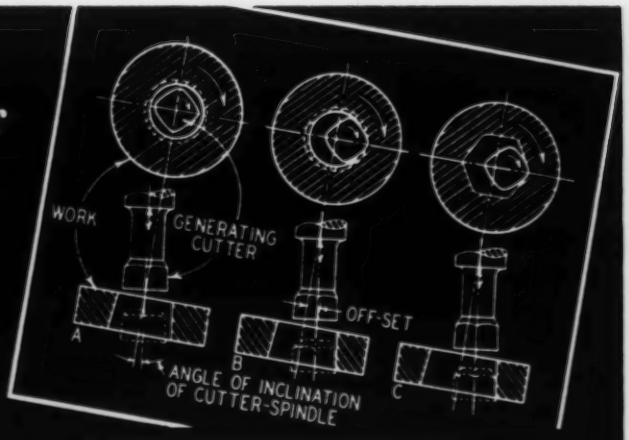
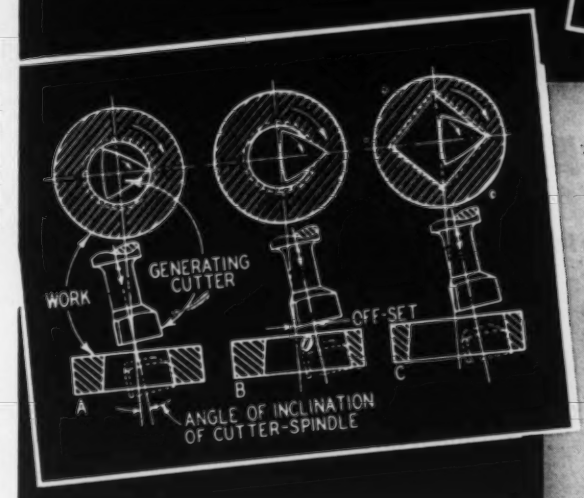
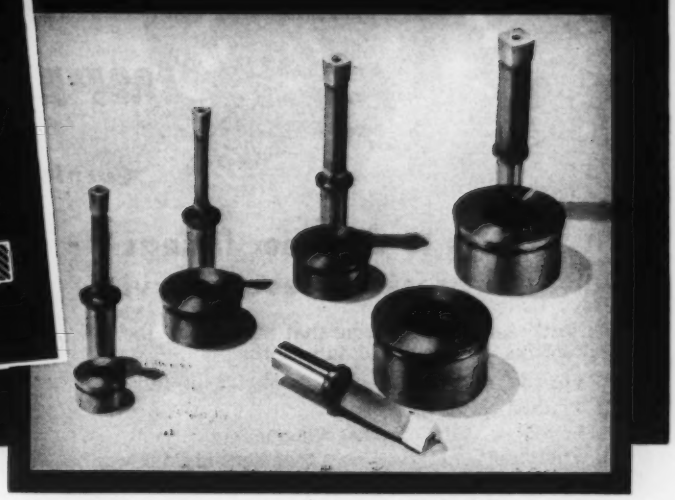
MAIL COUPON NOW

What every designer should know about THE ART OF GENERATING







Generating offers designers many advantages in producing an almost unlimited variety of contours. Produced by the relative motions of points, lines, or surfaces, all generated profiles are combinations of two basic surfaces: curved and straight.

Generating with a reciprocating cutter on the Fellows Gear Shaper is a low-cost method of producing a wide range of symmetrical or irregular contours, either internal or external. Gear Shaper versatility provides a choice of generating techniques—employing a cutter form conjugate to work shape, introducing a variable movement between cutter and work, or a combination of both methods.

Shown above are some trim dies and the cutters used to generate them: three-sided cutters generate the square holes and four-sided cutters the hexagonal holes. Cutter sides are curved surfaces conjugate to the straight surfaces on the dies. The drawing shows the steps in generating. A special bed tilting mechanism in the Gear Shapers provides a simple adjustment for the required taper angle on the dies.

Many other examples of interest to designers are shown in the booklet, "The Art of Generating with a Reciprocating Tool." Just write any Fellows Office.

THE FELLOWS GEAR SHAPER COMPANY
78 River Street, Springfield, Vermont
Branch Offices: 319 Fisher Building, Detroit 2
5835 West North Avenue, Chicago 39
150 W. Pleasant Ave., Maywood, N. J.
6214 West Manchester Avenue, Los Angeles 45

THE PRECISION LINE **Fellows** *Gear Production Equipment*

Circle 523 on page 19

The most important advance in tube fittings in 20 years!

New IMPERIAL HI-SEAL™

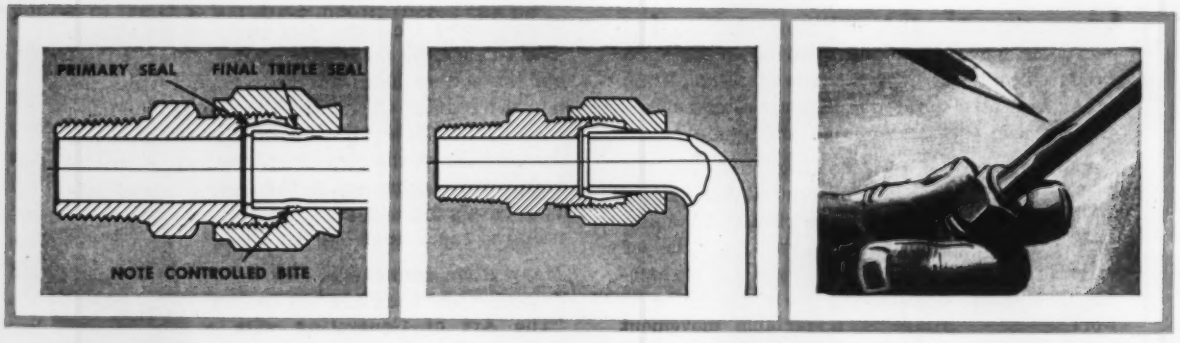
Furnished in steel and stainless steel

Successors to all other fittings for high-pressure, severe service

At last! A foolproof fitting that answers all the requirements of the "ideal tube fitting."

1. Positive butt-joints — no springing of tube.
2. Permits closer tube bends.
3. Eliminates tube torquing when making a joint.
4. Foolproof — Hi-Seal goes together only one way.
5. Assures repeated pressure-tight re-connections.
6. Joints stay pressure-tight beyond the burst pressure of tube — withstand severe vibration.
7. Threads are pitched for minimum torque in tightening — danger of stripping eliminated.
8. Far greater tolerance in tube length or placement during assembly.
9. Produced under continuous quality control methods to assure utmost reliability.

Big order? Sure — that's why the Hi-Seal is the most important advance in tube fittings in 20 years. Ask your Imperial distributor for complete information!



FOOLPROOF ASSEMBLY — There is only one way tubing can be inserted into sleeve, and only *one* way that the sleeve can go into fitting. Shoulder on sleeve prevents incorrect assembly. No need to disassemble joint to see if it has been properly made. Only an open-end wrench is needed for assembly.

CLOSER TUBE BENDS — Because of the extremely short tube entry and because no flaring is required, bends are made exceptionally close to the end of tubing. Hi-Seal fittings work in close quarters where other types of fittings cannot be used. Hi-Seal speeds assembly . . . drastically reduces field servicing time.

WITHSTANDS HIGHER PRESSURES — Joints made with Imperial Hi-Seal fittings stay pressure-tight beyond the burst strength of the tubing itself. Fitting is especially designed for hydraulic and other services where higher pressures are encountered. Can also be used in low and medium pressure applications as well.

Created and manufactured exclusively by . . .

IMPERIAL

THE IMPERIAL
513 S. RACINE AVE.

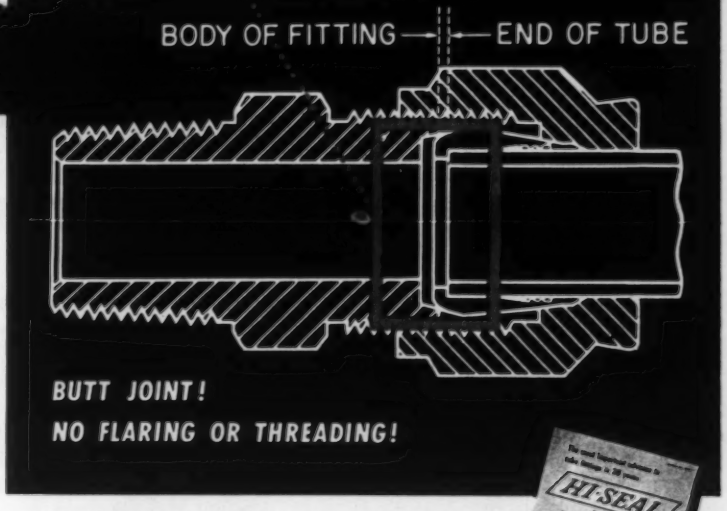
Industry's most complete

BUTT-JOINT FEATURE MAKES HI-SEAL EASIER TO INSTALL!

(a) Because Hi-Seal provides a positive butt-joint, and there is no tube entry into body of fitting, undesirable tube springing is eliminated. This is very important in the case of large-diameter, heavy-wall or hard-temper tubing where tube springing is extremely difficult and many times impossible.

(b) Note how tube "bottoms" on shoulder of sleeve (see diagram). Camming action of nut results in a controlled bite of sleeve into tubing. Serrated edges inside sleeve provide a triple, leak-proof seal. Finally, a perfect circumferential seal is made by tapered edge of sleeve in recess of body.

(c) Hi-Seal fittings are furnished complete with body, nut and sleeve assembled. Available with long Dryseal pipe threads or with straight threads with O-Ring seal.



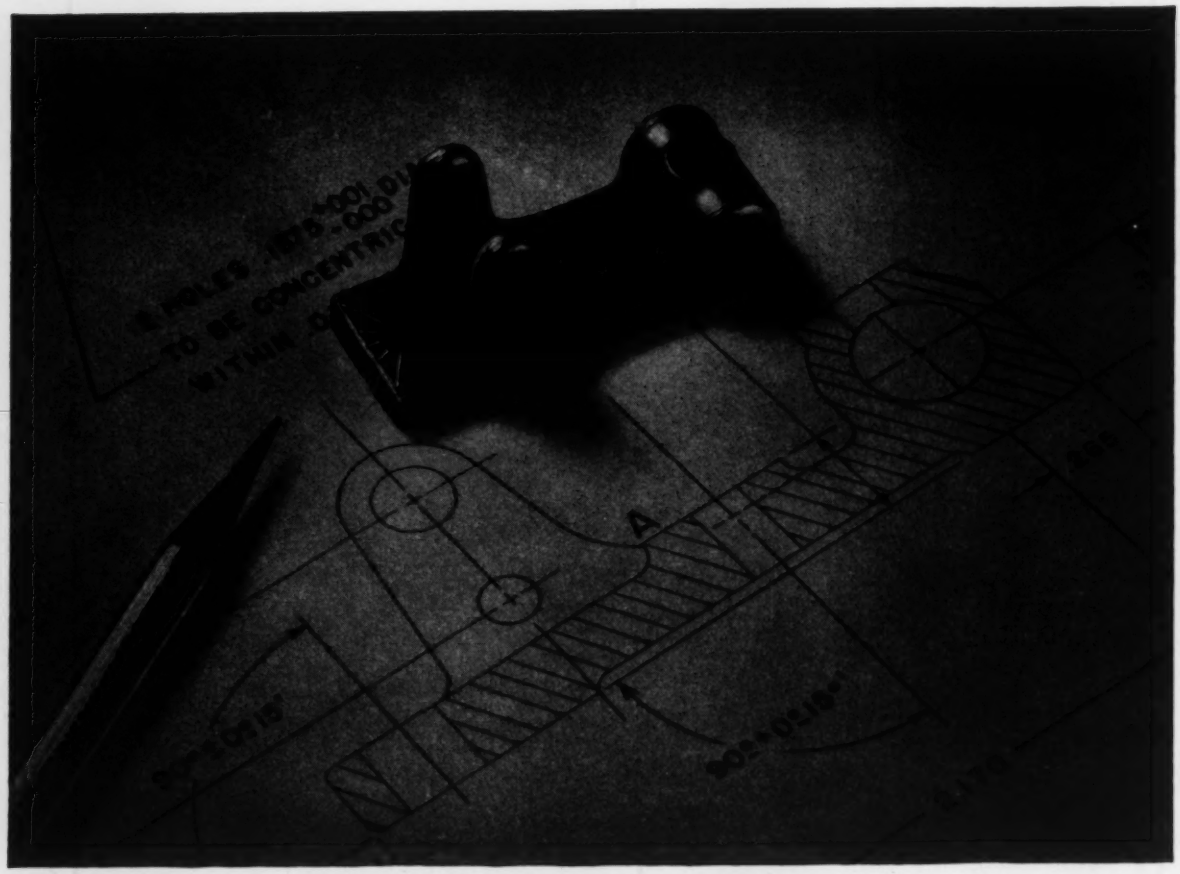
Just off the press — highly informative bulletin No. 3061 on Hi-Seal principle and applications. Includes engineering recommendations, dimensional data, complete listing of types and sizes for ⅛" to 1½" O.D. tubing.

BRASS MANUFACTURING COMPANY

CHICAGO 7, ILLINOIS *In Canada:* 334 Lauder Ave., Toronto, Ontario

Emblem of Quality

line of tube fittings and tubing tools



Produced for half the cost — Part of the "Vapoflash," this Inconel alloy precision casting withstands searing gas turbine exhaust temperatures.

Design big savings into small parts with Inco precision investment casting

Many small parts can be designed to cost less by taking advantage of Inco precision casting.

Manning, Maxwell & Moore, Inc., Aircraft Products Division, reduced costs 50% on the part shown above. It's the body of the "Vapoflash," which measures exhaust temperatures in gas turbines. To withstand heat up to 1500°F., it's made of Inconel* nickel-chromium alloy.

Costs argued against two obvious methods of production. Machining from bar stock would take *17* operations. Machining from sand castings would take *8* — still too many.

A dilemma? *Easily solved.* Designed to be precision investment cast by Inco, the part takes only 5 finish machining steps.

High precision . . . less machining

Whenever you have a high-melting-point metal part which is 6 inches x 5 inches or smaller, weighs under 3 lbs., requires starting tolerances as close as plus or minus .005 inch per linear inch, and needs 5 or more fabrication steps, consider precision casting. It often gives required precision with less machining.

Send us a sample or blueprint. Our Engineering Department will be glad to submit their recommendations and quotations on Inco precision investment castings.

*Registered trademark

The International Nickel Company, Inc.
67 Wall Street New York 5, N. Y.

5 Advantages of Inco Precision Castings

- **Save up to 60% of production costs.**
- **Longer life with harder alloys.**
- **Little or no machining required.**
- **Wider design latitude.**
- **Higher alloys at lower cost.**

"Cast to Outlast"

This handsome, 16-page booklet shows how to keep costs in line on small parts. Illustrated with many case histories. Write for a copy . . . now.

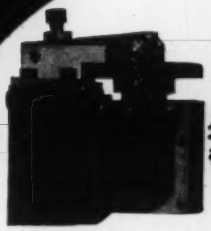
INCO TRADE MARK

Inco Castings . . . *Precision, Sand, Centrifugal*

CONTROLS YOU CAN depend on

WATERMAN CONTROLS

for accuracy—dependability safety—low maintenance cost



SOLENOID VALVES

For working pressures to 3000 psi. Remote control of hydraulic systems for handling non-corrosive fluids.

LOOK TO WATERMAN

MICRONIC LINE FILTERS

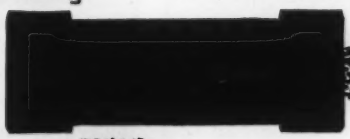
Operating pressures to 3000 psi. 40 micron filtration. Replaceable elements. Available in ⅜" and ¾" NPT.

FOR THE ANSWER TO

ADJUSTABLE FLOW REGULATORS

Full range from 0.5 GPM to 20 GPM. All Waterman Flow Regulators maintain a constant rate of flow regardless of work resistance or pressure fluctuations.

YOUR FLOW CONTROL



CHECK VALVES

One piece. Leak proof. Nylon Poppet. Aluminum body. Low pressure drop.

REQUIREMENTS

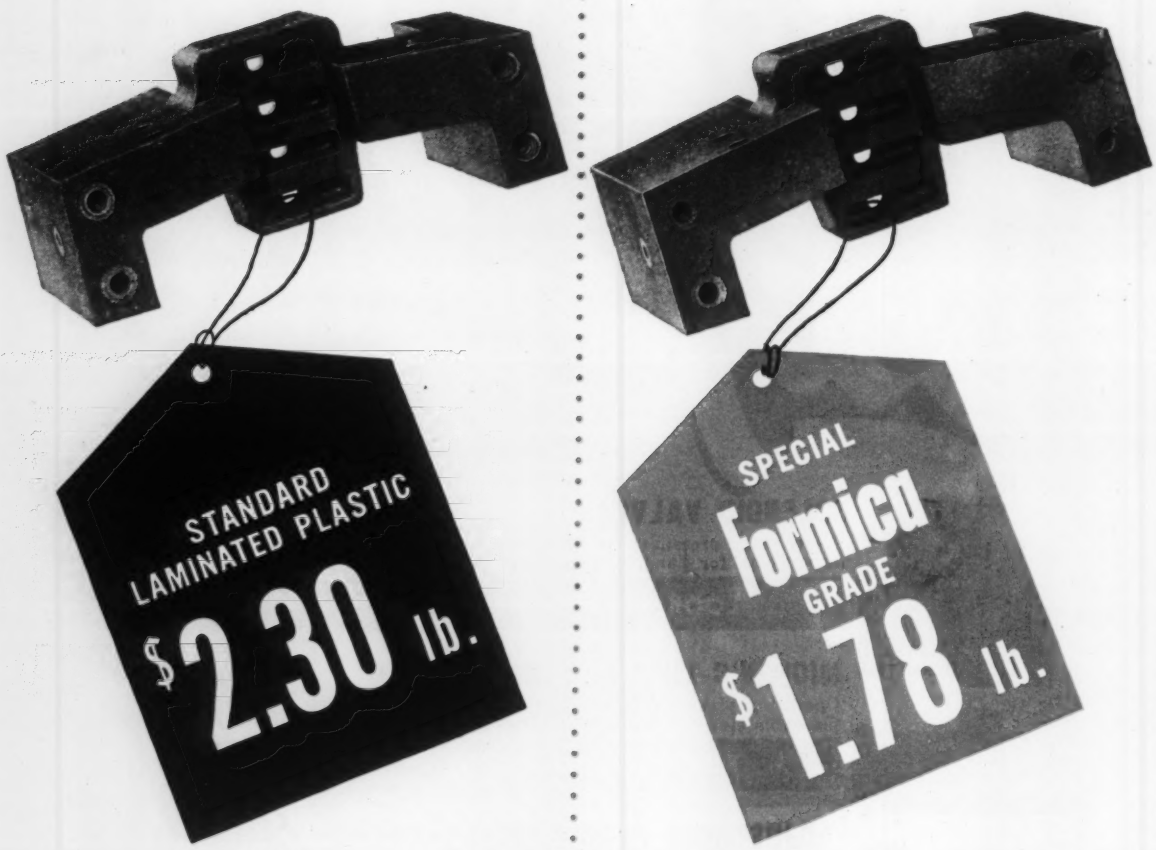
Write for bulletin F of any of these products

UNLOADING VALVES

UNLOADING VALVES for system pressures to 3000 psi. Flow rates to 30 G.P.M. Fast acting, easily adjustable, maintain desired pressure settings without continuous readjustment. Hardened poppets eliminate leakage. Large passages assure maximum flow with minimum pressure loss.

WATERMAN ENGINEERING COMPANY

725 CUSTER AVENUE • EVANSTON, ILLINOIS



Formica IMPROVED FABRICATED PART... SAVED CUSTOMER 23%!

Formica studied performance requirements, developed a special grade, produced a better part, and saved the customer 52c a pound.

Are you buying laminated plastic properties you don't need? Or are you paying the penalty of poor product performance because you've been short-changed on essential properties?

You can never be sure until you have a Formica fabricating engineer check your performance requirements. Tell him what you need, where and how you'll be using your fabricated part. Then he'll select the *one grade* that's best and most economical for you.

With 52 standard grades, and a competent research staff to develop special new ones, there's never any compromise with grade selection at Formica. And design modifications recommended by Formica fabricating engineers will further help to produce a better part, frequently at big savings.

This fabricating service is part of Formica-4, designed to give you the best grade at lowest cost for your application. Call your Formica district office or send us your blueprints and your performance requirements. Formica Corporation, subsidiary of American Cyanamid, 5-4545 Spring Grove Ave., Cincinnati 32, Ohio.

Your *blueprint* tells only *half* the story...

... tell us your performance requirements and we'll save you money

Circle 526 on page 19

MORE OF THE GARLOCK **2,000**

The low coefficient of friction and longer service life of Garlock Teflon seals has been used to great advantage by a large producer of power steering equipment. The switch to Teflon substantially reduced both manual turning effort and wear in the power steering mechanism.

These seals were designed by Garlock engineers to do a particular job better. They are typical of "the Garlock 2,000" . . . two thousand different styles of packings, gaskets, and seals to meet every conceivable need . . . the *only* complete line available. That's why your Garlock representative can give you *unbiased* recommendations. Call him at the start of your next project, his experience will save you time and money. Write today for new Garlock Teflon Catalog AD-155.

**DuPont Company Trade-mark*

THE GARLOCK PACKING COMPANY, Palmyra, New York

For Prompt Service, contact one of our 30 sales offices and warehouses throughout the U.S. and Canada

GARLOCK

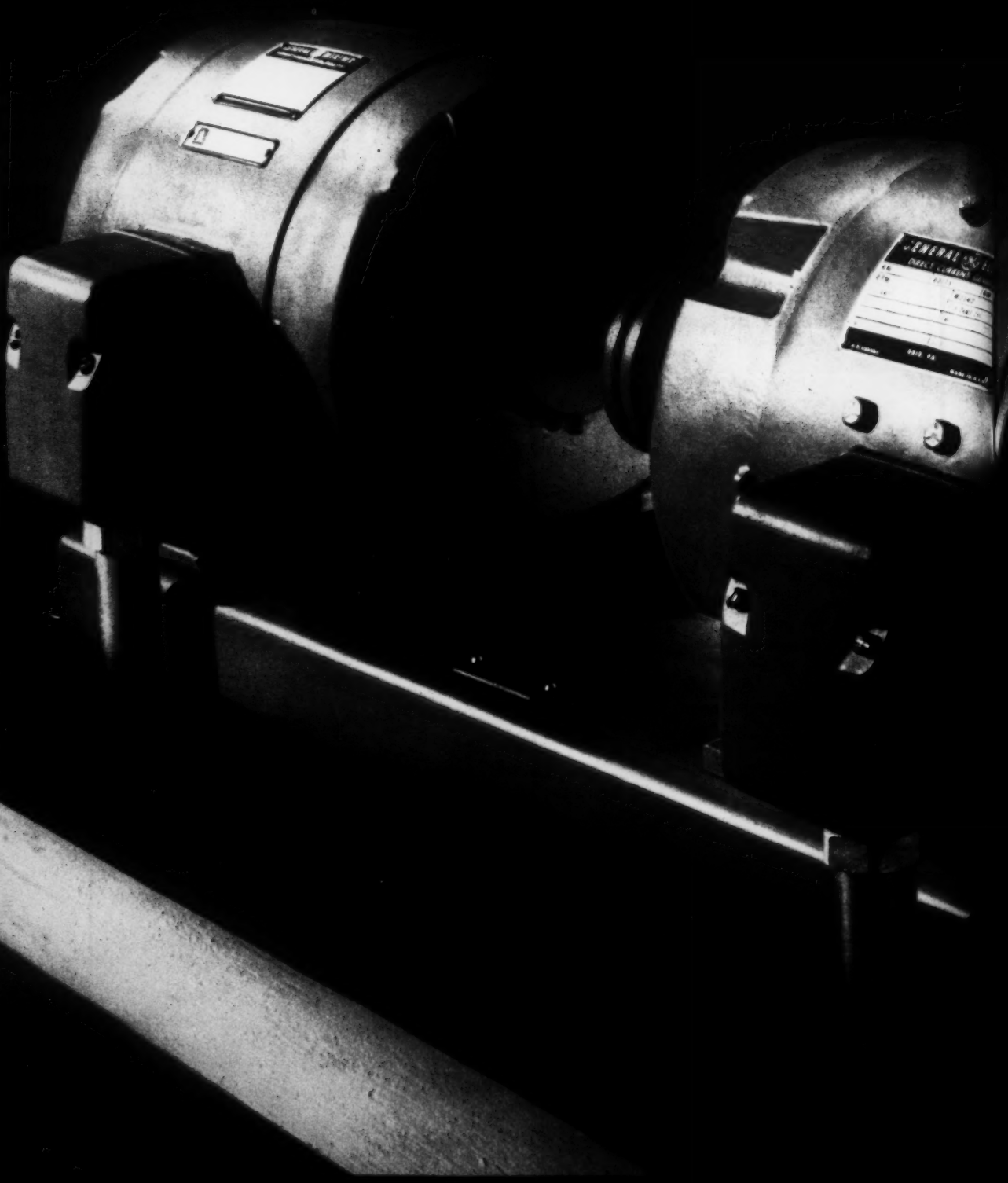
Packings, Gaskets, Oil Seals, Mechanical Seals, Rubber Expansion Joints

Circle 527 on page 19

Circle 528 on page 19→

To help you cut production costs . . .

NEW General Electric



c D-c Power Source

KINAMATIC* — — — a new standard in direct-current generators and motor-generator sets—designed to give you higher output at less cost.

As a progressive manufacturer, you are faced with the problem of boosting factory output and beating rising production costs. Where your production process involves adjustable speed, tough duty cycles, frequent reversals or speed matching, you may have already applied the performance advantages of d-c drives. To help you further boost production and reduce your automation costs, completely new sources of constant and adjustable-voltage d-c power are now available—General Electric d-c Kinamatic generators and m-g sets, ¾–100 KW.

More Power Per Dollar—D-c Kinamatic generators pack more power per frame size than any previously designed G-E generator. Nine new kilowatt ratings more closely match both the power requirements of your standard d-c drive motors and the power output of standard prime-moving a-c motors. This new matching gives you a more efficient, more compact adjustable-voltage drive at lower cost.

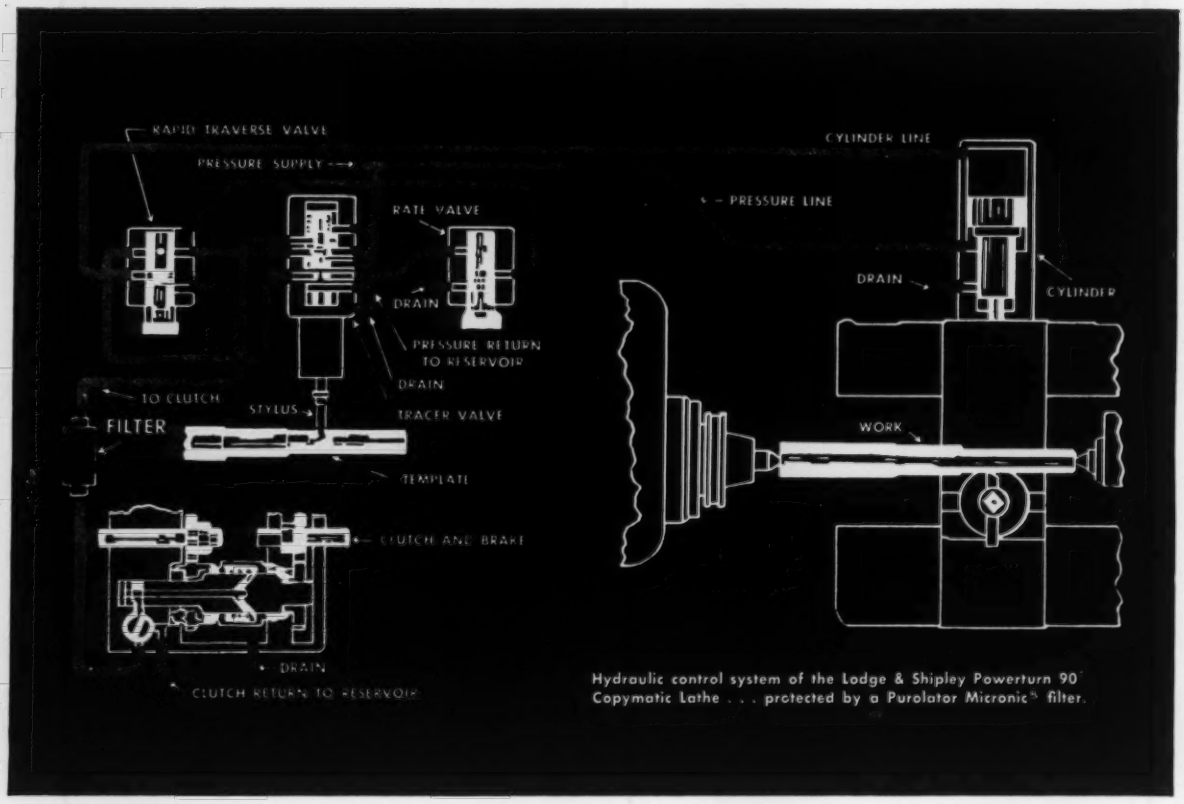
And a Lot More—A d-c Kinamatic generator or motor-generator set can give you much more than savings on initial automation costs. If you would like to know more about the construction details, advanced performance characteristics and money-saving maintenance features of d-c Kinamatic generators and m-g sets, we would like to have a G-E Apparatus Sales Representative call on you. Or, if you prefer, we will send you copies of GEA-6461 and GEA-6355. *Direct Current Motor and Generator Department, General Electric Company, Erie, Pennsylvania.* 813-2

* Trade mark of General Electric Company

Progress Is Our Most Important Product

GENERAL ELECTRIC

XUM



Hydraulic control system of the Lodge & Shipley Powerturn 90° Copymatic Lathe . . . protected by a Purolator Micronic® filter.

Designed for highly accurate control ...fully protected by Purolator Filtration

On a very successful automatic duplicating lathe, this hydraulic control system makes possible both quick, simple operation and a high degree of sensitivity and accuracy. Reliable and uninterrupted operation of a system like this is dependent upon freedom from contaminants. That's why the Lodge and Shipley Company, its manufacturer, made Purolator Micronic® filters an integral part of their hydraulic system.

Purolator engineers recommended a standard filter from their stock of over 2000 models. It more than met the system's special requirements.

The controlled porosity of Purolator's Micronic element evenly filters out contaminant particles as small as .000039 inch. And because it's made of plastic-impregnated cellulose, the Micronic element is not affected by high temperatures, water, or oil.

Filtration For Every Known Fluid

PUROLATOR

PRODUCTS, INC.

Rahway, New Jersey and Toronto, Ontario, Canada

Filtering information for product designers is available in our 32 page "Filtration Manual for Product Designers". Just enclose 25¢ to cover postage and handling. Address Dept. P5-118

Circle 529 on page 19

70% LIGHTER

than comparable rubber-edged metal hangers . . . costs less too

NYLOCLIP™

NYLON CABLE HANGERS

For strong, sure support . . . for sustained periods in temperature extremes from −60°F to 250°F . . . these new, tough, lightweight, molded nylon cable hangers give you all the important features of metal, *plus.*

Even under severe stress, NYLOCLIP's high physical strength holds pre-formed shape indefinitely . . . undamaged by oils, gasoline, alcohol, hydraulic fluids.

Self-insulating nylon is high dielectric non-conductor; eliminates hysteresis losses, grounds, shorts.

Cable insulation fully protected by rounded edges, matte finish inside surface of NYLOCLIP. Stud hole serrations running parallel to cable insure automatic alignment when screw is tightened – prevent cable chafing. Available in 17 standard sizes to accommodate cables or bundles from ⅛" to 2".

Meets MIL-STD-242 and NAVORD OSTD 600-7-3.02.29 (int.)

For proof of performance, send for samples . . . to your specified sizes.

rugged strength

of Nyloclip supports this man's full weight . . . 247 lbs.!

BURNDY

58-10

Norwalk, Connect. • Toronto, Canada • Other Factories: New York, Calif., Toronto • Export: Philips Export Corp.

Circle 530 on page 19

WINSMITH® SPEED REDUCERS

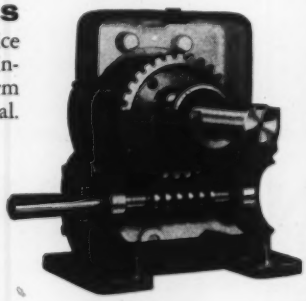
the standard line of Speed Reducers for every design problem!

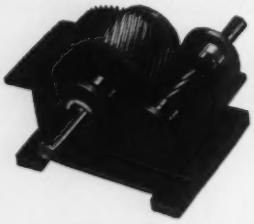
The wide range of models and sizes in the Winsmith line enables most speed reducer users to select a unit "custom-made" for the job on hand from the standard stock line. For speed of delivery . . . for economy . . . for performance . . . make Winsmith your source for speed reducers from 1/100 to 85 h.p. in ratios of 1.1:1 to 50,000:1.

IF YOU HAVE A SPECIAL PROBLEM—consult the Winsmith Representative in your area or write direct to our Engineering Department.

WORM GEAR REDUCERS

Available in single or double reduction models for service in either intermittent or continuous operation. Units include right angle or parallel shafts; worm on top or worm on bottom; all worm gear or combined worm and helical.



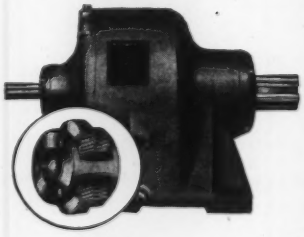


HELICAL GEAR REDUCERS

Single reduction, parallel shaft units for small ratios. Cast iron gears. Hardened and accurately ground alloy steel pinion shafts.

DIFFERENTIAL GEAR REDUCERS

Winsmith patented differential gear reducers differ from ordinary planetary systems in that the planetary and secondary gears are made integral to form a unified planetary element. Tooth alignment is maintained because the planetary gears automatically float into position resulting in equalized load distribution. Parts are never increased in number regardless of the ratio of reduction. Overall dimensions of a given size always remain the same . . . whether 1.1:1 or 50,000:1.



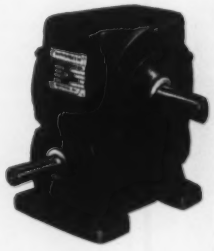
SINGLE REDUCTION WORM GEAR TYPE

SERIES CB, CT, CV

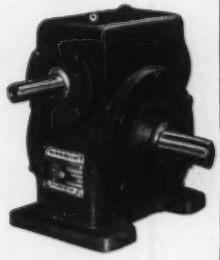
14 Sizes — .01 hp to 34 hp

Ratio Range — 5:1 to 77:1

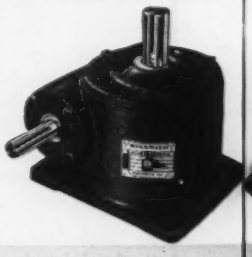
Maximum Output Torque 142 to 34,767 in. lbs.



CB — WORM ON BOTTOM



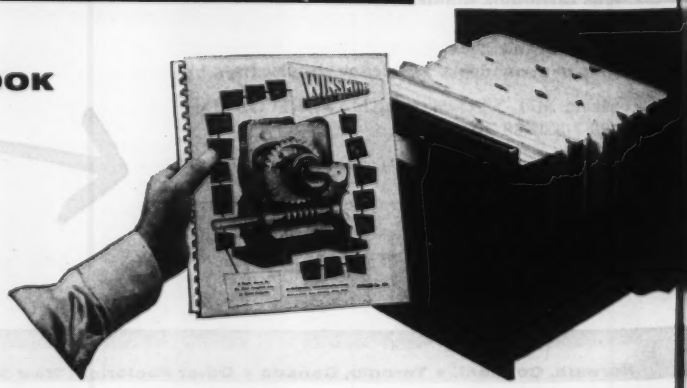
CT — WORM ON TOP



CV — VERTICAL

ADD THIS IMPORTANT BOOK TO YOUR FILES!

Winsmith's New Catalog containing complete selection information on 147 speed reducer sizes.



DOUBLE REDUCTION WORM AND HELICAL GEAR TYPE

SERIES CBX, CTX, CVX

10 Sizes — .3 hp to 11.86 hp

Ratio Range — 42:1 to 231:1

Maximum Output Torque
1331 to 34,767 in. lbs.

DOUBLE REDUCTION WORM GEAR TYPE

SERIES CBD, CTD, CVD

12 Sizes — .018 hp to 7.41 hp

Ratio Range — 60:1 to 4460:1

Maximum Output Torque
650 to 34,767 in. lbs.

1. DOUBLE REDUCTION WORM GEAR TYPE
9 Sizes — .006 hp to 7.319 hp
Ratio Range — 25:1 to 3850:1
Maximum Output Torque
146 to 34,290 in. lbs.

2. SINGLE REDUCTION HELICAL GEAR HORIZONTAL TYPE
3 Sizes — .05 hp to 18.86 hp
Ratio Range — 3.06:1 to 12.66:1
Maximum Output Torque
294 to 3682 in. lbs.

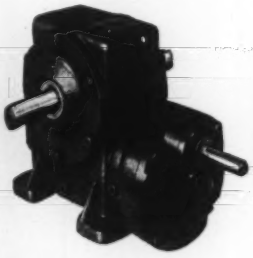
3. TWO SPEED REDUCTION WORM AND SPUR GEAR TYPE
2 Sizes — .01 hp to 6.17 hp
Ratio Range — 5:1 to 163:1
Maximum Output Torque
333 to 3089 in. lbs.

DIFFERENTIAL REDUCERS

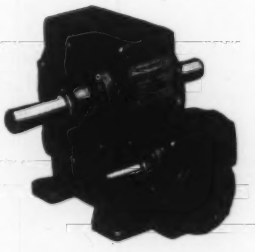
.12 hp to 81.51 hp

Ratio Range 1.1:1 to 50,000:1

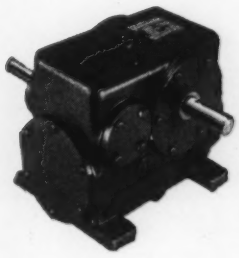
Maximum Output Torque
50 to 113,000 in. lbs.



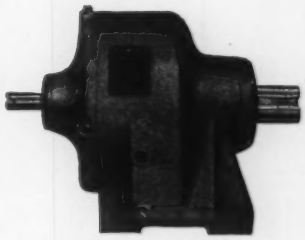
CBX — WORM ON BOTTOM



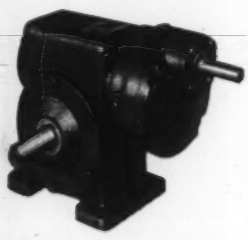
CBD — WORM ON BOTTOM



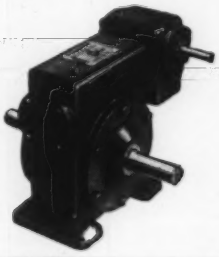
1. SERIES **DBI**



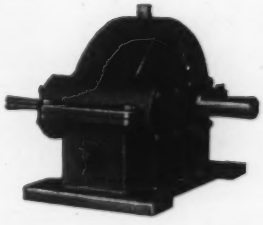
HORIZONTAL



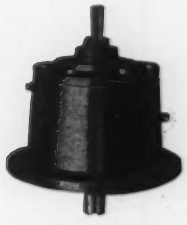
CTX — WORM ON TOP



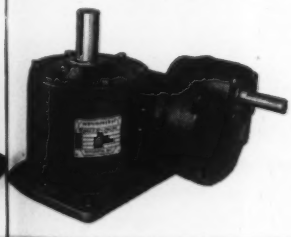
CTD — WORM ON TOP



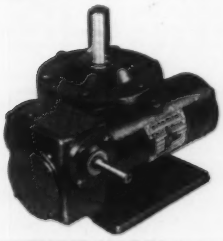
2. SERIES **700, 800, 900**



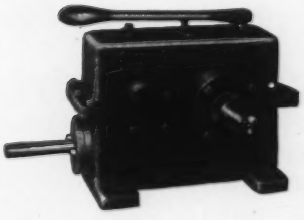
FLANGE MOUNTED



CVX — VERTICAL

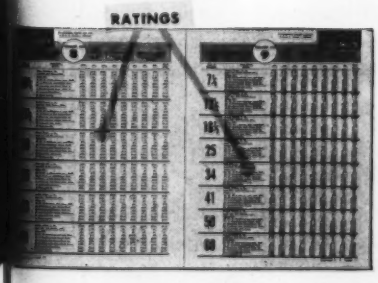


CVD — VERTICAL



3. SERIES **TSR**

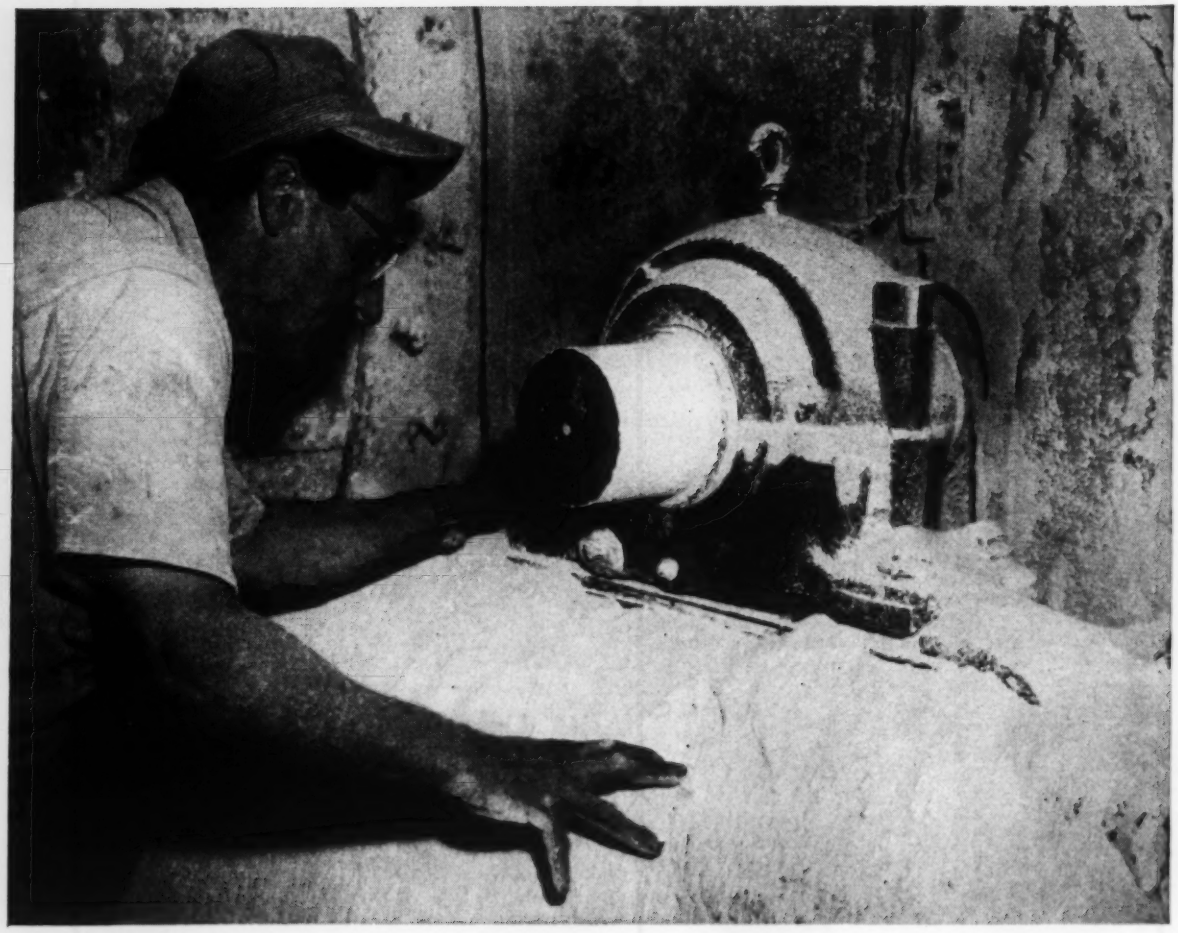
VERTICAL MOTORIZED



You'll rate this catalog as one of the most important and useful tools ever presented to design engineers. In addition to complete selection information such as weights, dimensions, parts, ratios and ratings on the reducers it describes, this book contains selection factors, lubrication charts, character of load tables *plus* a complete engineering section devoted to examples and solutions of typical power transmission problems.

This wealth of useful information is yours for the asking . . . request Catalog 155 — on company letterhead, please.

WINSMITH, Incorporated • *16 Elton Street, Springville, (Erie County) New York*



Maintenance cut 49% with SKF® anti-friction bearings

SKF "Triple-Seal" Pillow Blocks, used by an eastern limestone producer in pulverizing tube mills, have saved thousands of dollars since their installation in 1948.

In comparable operating periods, counter-shaft failures dropped from 11 to 2, bearing maintenance costs were cut 49%, production increased 70%, power savings averaged 10% to 20%.

Required to operate in a highly abrasive "snowstorm" of powdered limestone, these triple-sealed units continue to save money for the user. They will do the same for you.

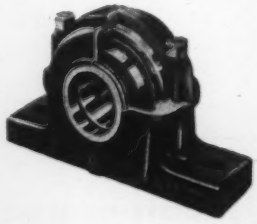
For further information on how these remarkable "Triple-Seal" Pillow Blocks can be applied most effectively to your products, get in touch with your local **SKF** Sales Office. 7738

SKF

EVERY TYPE—EVERY USE

Ball Bearings
Cylindrical Roller Bearings
Spherical Roller Bearings
Tapered Roller Bearings ("Tyson")

*Reg. U.S Pat. Off Tyson Bearing Corporation



SKF INDUSTRIES, INC., PHILADELPHIA 32, PA.

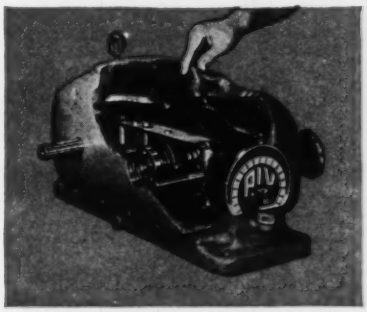
Circle 532 on page 19

Because it uses a positive chain rather than frictional elements to transmit power...LINK-BELT P.I.V. delivers

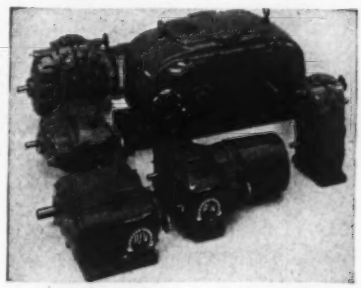
variable speeds with unvarying accuracy

Throughout industry, chain drives have long been preferred as a simple, versatile method of transmitting power positively and accurately. But it was not until the conception of Link-Belt P.I.V. that this advantage was adapted to variable speed drives. With its self-tooth-forming chain principle, P.I.V. provides instant selection of any speed between its maximum and minimum settings without stopping the machine.

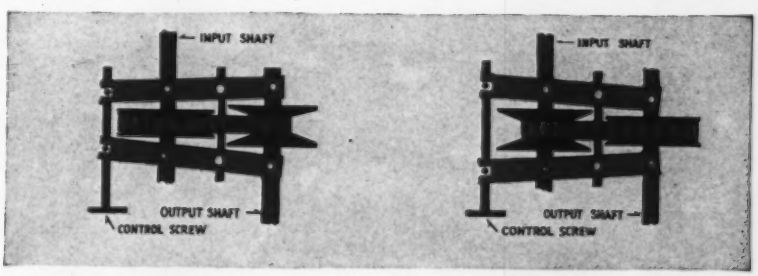
TO CHANGE OUTPUT RPM, operator merely turns convenient handwheel to selected speed, indicated by easy-to-read dial.



AUTOMATIC ADJUSTMENT of chain tension—by turning hand screw—assures accuracy during long life of drive.

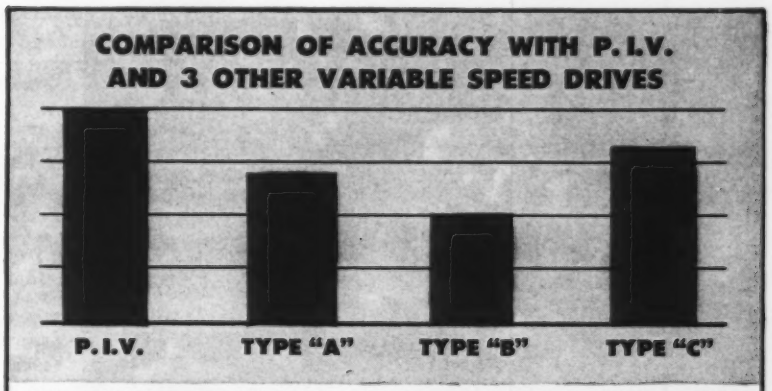


P.I.V. drives are built in capacities from ½ to 25 hp, in 8 sizes and 16 types. Compactness permits installation as a separate unit or built-in part of driven machine.



AT MAXIMUM SPEED SETTING . . . chain grips wheel grooves near perimeter of input side and near center of output side.

AT MINIMUM SPEED SETTING . . . relative position of chain to wheels is reversed, delivering low output shaft rpm.



Using P.I.V. as a standard, bars indicate comparative ability to maintain desired rpm from no-load to full-load relative to three conventional variable speed drives. Chain principle of P.I.V. minimizes speed drop—loss of accuracy which may affect product quality and uniformity. Operating independent of friction, P.I.V. provides instant, positive selection regardless of load or atmospheric conditions.

THE exclusive P.I.V. chain consists of a series of overlapping steel slats. These are free to move transversely from side to side, singly or collectively, serving as teeth. The chain meshes with radially grooved wheels, which are cut at a constant depth toward the wheel periphery. Beveled sides of the grooves offer gripping areas . . . provide a positive, non-slip contact at any speed, under all loads.

All-metal construction of P.I.V. is unaffected by atmospheric conditions. Housings are of close-grained gray iron—internal moving parts are automatically splash-lubricated.

You'll find much interesting and valuable information concerning P.I.V. in Book 2274 Link-Belt also makes mechanical, hydraulic, electronic and pneumatic controls for regulating these drives automatically, and these are detailed in Book 2349. Ask your Link-Belt office.

LINK-BELT COMPANY: Executive offices, Prudential Plaza, Chicago 1. To Serve Industry There Are Link-Belt Plants, Sales Offices, Stock Carrying Factory Branch Stores and Distributors in All Principal Cities. Export Office: New York 7; Canada, Scarboro (Toronto 13); Australia, Marrickville, N.S.W.; South Africa, Springs. Representatives Throughout the World. 14.104

Circle 533 on page 19

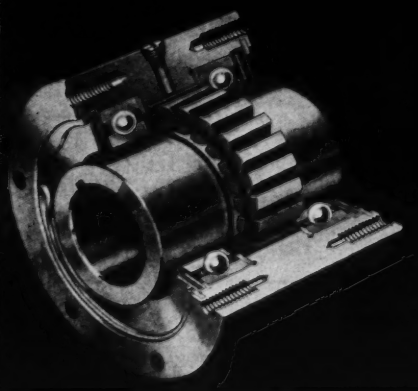
Roomful of restless men

You're looking at a roomful of design engineers. Like yourself, perhaps, they push themselves to achieve a "let's do it better for our customers" result. It's idea-creating work in a challenging mental atmosphere.

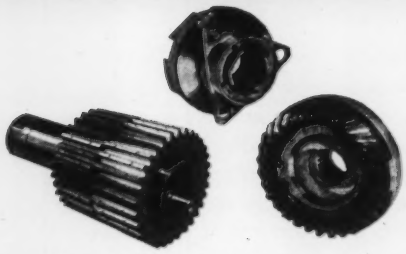
They work mostly on special clutch applications . . . been doing it for years. When a job poses a new problem they ask themselves: "Can we use one of our standard designs in this assembly rather than create a new one?" . . . More often than not their answer can be yes.

Secret of this adaptability is the result of pioneering engineering experience combined with Formsprag's basically simple design (see cutaway photo below). Imagine how these skilled designers can modify components to cover an enormous range of applications. The cost is usually only slightly above that of a standard model.

Drawing on their long experience with special application problems, Formsprag engineers are able to custom-tailor clutches from production line parts. You can rest—and plan—assured that Formsprag will design, build prototypes and volume produce special clutches to your complete satisfaction.



Standard Ball Bearing All-Purpose Formsprag Clutch. Note its simplicity of design. Between inner and outer races a full complement of sprags is inserted. Energizing springs hold sprags in contact. Formsprag construction allows more sprags to be inserted in a smaller area than other clutch designs. Result: greater torque capacity in a smaller clutch.



Special application Formsprag clutches like these can be priced advantageously when the application calls for use of Formsprag's vast fund of developmental engineering know-how. Let us send you literature that discusses in detail Formsprag clutches for standard and special applications.

Over-Running, Indexing and Backstopping Clutches for aircraft, automotive, and various industrial applications.

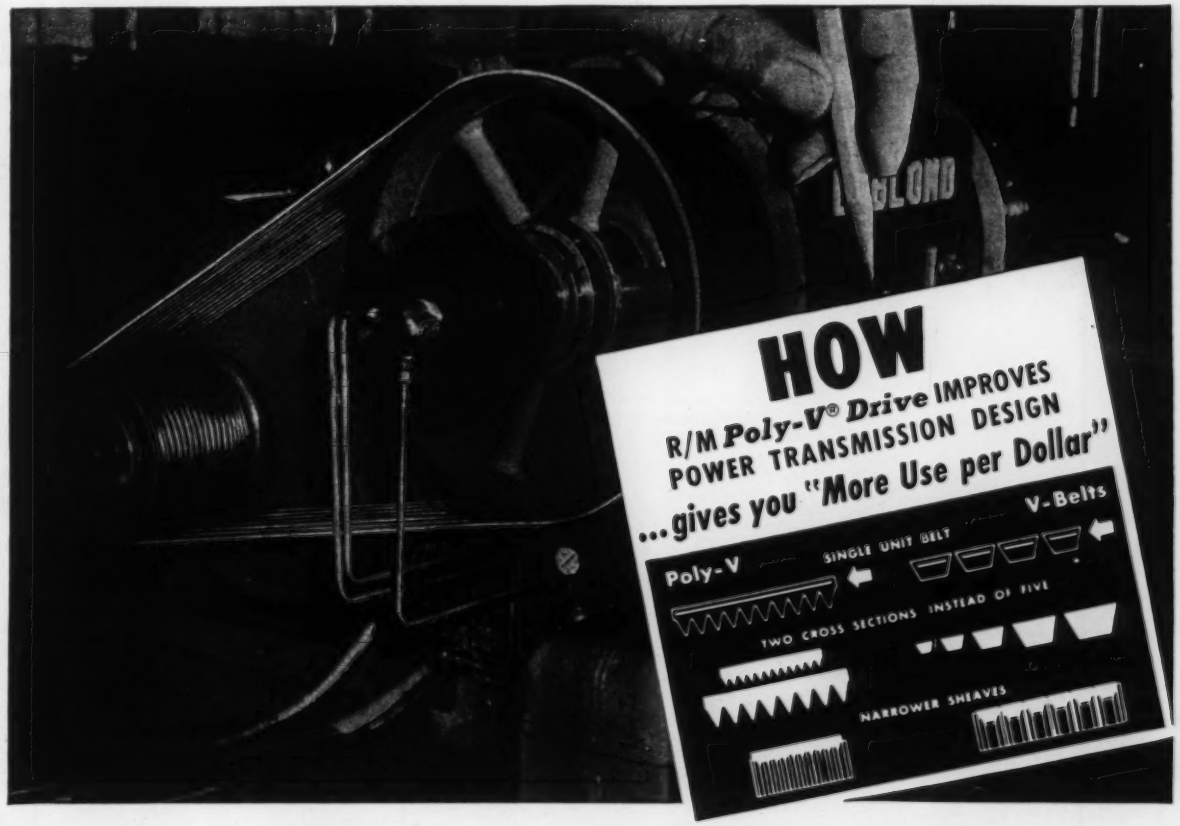
FORMSPRAG COMPANY

23603 HOOVER ROAD, VAN DYKE, MICHIGAN

World's Largest Exclusive Manufacturer of Over-Running Clutches

Distributors in principal cities

(A4-11B)



This *Poly-V® Drive* Saved $2,000 in Machine Cost!

No other belt drive delivers as *much power* in as *little space* as R/M Poly-V Drive. Designers of the giant boring lathe pictured above took advantage of this exclusive Poly-V feature—specified a single unit Poly-V Drive to replace the 13 multiple V-belts previously used on the lathe drive. Results? Sheave width was reduced 30%, eliminating the need for a cumbersome outboard bearing to handle excessive drive weight. . . . This *saved $2000 in the cost of the machine.*

It's another example of why design engineers are calling the patented R/M Poly-V Drive the ideal drive for heavy duty power transmission. Poly-V employs a single, endless V-ribbed belt running on sheaves designed to mate precisely with the belt ribs. You get up to 50% more power in the *same* space as a multiple V-belt drive, or *equal* power in as little as 2/3 the space —with *less* shaft overhang, less drive weight!

Space and weight saving features are just part of the story. There are no belt "matching" problems with Poly-V Drive and just *two* belt cross sections meet every heavy-duty power transmission requirement! Poly-V Drive maintains constant pitch diameter at all loads. Belt speed ratio and belt position are maintained from no load to full load to assure a smoother, cooler running drive . . . reduce belt and sheave wear.

Advantages of this amazing new drive concept add up to improved machine design and real economy—"More Use per Dollar"—for both new and existing equipment. Let R/M engineers work with you on your power transmission problems. Contact an R/M representative . . . or write for Poly-V* Drive Bulletin #6638.

CONDOR V-BELTS • R/M SUPER-POWER V-BELTS

Write for Bulletin #6868 on the complete line of Condor V-Belts for regular service on conventional V-belt drives. Also write for Bulletin #6628 on R/M Super-Power V-Belts with 40% more Horsepower capacity where needed.

*Poly-V is a registered Raybestos-Manhattan Trademark

RM-829

MANHATTAN RUBBER DIVISION—PASSAIC, NEW JERSEY

RAYBESTOS-MANHATTAN, INC.

Other R/M products include: Industrial Rubber • Fan Belts • Radiator Hose • Brake Linings • Brake Blocks • Clutch Facings • Asbestos Textiles • Packings • Engineered Plastic and Sintered Metal Products • Laundry Pads and Covers • Bowling Balls

Circle 535 on page 19

CALL ON R/M ENGINEERING SERVICE

A CLEAR CASE OF QUALITY . . . R/M FABRIC PISTON CUPS

Designers of hydraulic and pneumatic equipment like these quality features built into R/M Fabric Piston Cups because they mean extra performance and longer wear:

1. Precision molding—Note the clear definition of contours, smooth surfaces, clean trimming—all evidence of top-flight molding practice.

2. Superior impregnation—Cut an R/M Fabric Piston Cup and you will see how R/M's special method gives deeper, more thorough penetration of the compound into the fabric. This keeps wicking action from destroying the cup internally and gives greater resistance to ply delamination.

3. Controlled tolerances—Careful quality control insures dimensional uniformity, consistent hardness, and strict adherence to industry standard sizes.

R/M Fabric Piston Cups are available to fit cylinders from ½ to 12 in. in diameter. Types are furnished in varying degrees of hardness for pressures up to 1500 psi and in different compounds to meet specific operating conditions.

For booklet shown, or other data, write, phone or wire:

PACKING DIVISION
Raybestos-Manhattan, Inc.
Passaic, N.J. • GRegory 3-2000

ASBESTOS TEXTILE DIVISION
Raybestos-Manhattan, Inc.
Manheim, Pa. • Manheim 5-2211

R/M

SPECIALISTS IN ASBESTOS, RUBBER, SINTERED METAL, ENGINEERED PLASTICS

Brake Blocks, Linings and Clutch Facings

Fan Belts and Radiator Hose

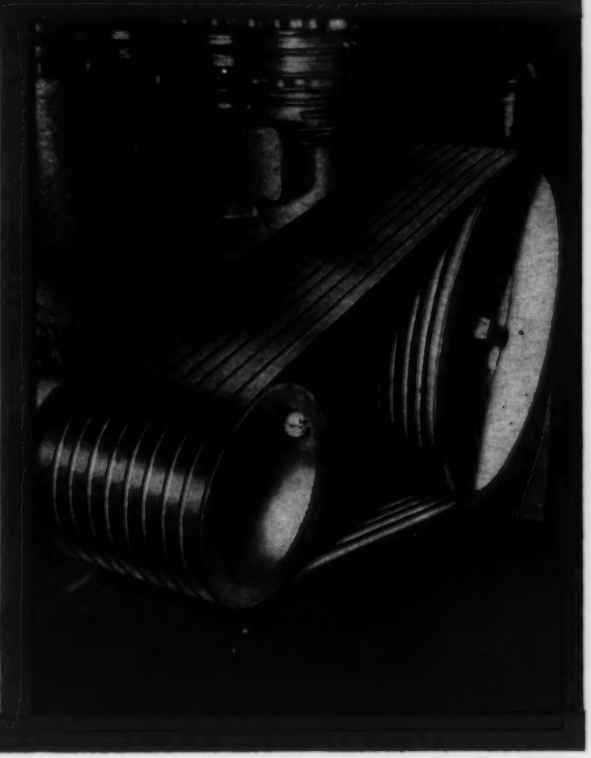
Mechanical Packings and Gaskets

Abrasive and Diamond Wheels

Industrial Drive Belts

Industrial and Automotive Hose

FOR HELP IN SOLVING YOUR PROBLEMS



FRICTION MATERIALS

Unlike other manufacturers, R/M works with *all* kinds of friction materials, from asbestos to sintered metals. This means that when you consult an R/M engineer you can be sure of completely unbiased advice on which materials are best for your application.

Raybestos-Manhattan has been the world's largest maker of friction materials for over 50 years. Whatever your brake or clutch requirements, count on R/M experience, and R/M manufacturing and testing facilities, for a friction material exactly suited to your needs.

Write for your copy of R/M Bulletin No. 500. It's loaded with practical design and engineering data on all R/M friction materials.

EQUIPMENT SALES DIVISION
Raybestos-Manhattan, Inc.
Bridgeport, Conn.
Edison 7-3341

R/M SUPER-POWER V-BELTS

On heavy duty drive designs you can increase drive capacity as much as 40% with R/M Super-Power V-belts . . . *without* changing present drive design! Or you can save space in *new* drive designs by using narrower sheaves and fewer belts to meet horsepower specifications. New stretchless, super-strength synthetic cords give R/M Super-Power V-belts the extra power capacity. Straight sidewalls give them better tensioning and grip . . less slip and longer life on the most rugged drives. All-synthetic rubber construction makes them oilproof, non-spark and heat resistant. You'll find the same engineering in Condor V-belts for general drive applications. Whether your application calls for V-belts, rubber hose, conveyor belts, flat transmission belting or precision molded or extruded parts . . . let R/M specialists work with you on your design problems.

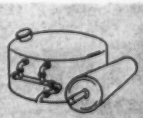
For booklet shown, or other data, write, phone or wire:

MANHATTAN RUBBER DIVISION
Raybestos-Manhattan, Inc.
Passaic, N.J.
GRegory 3-2000

RAYBESTOS-MANHATTAN, INC.

FACTORIES: Passaic, N.J. • Bridgeport, Conn. • Manheim, Pa. • No. Charleston, S.C. • Crawfordsville, Ind. • Neenah, Wis. • Peterborough, Ontario, Canada

Conveyor Belts



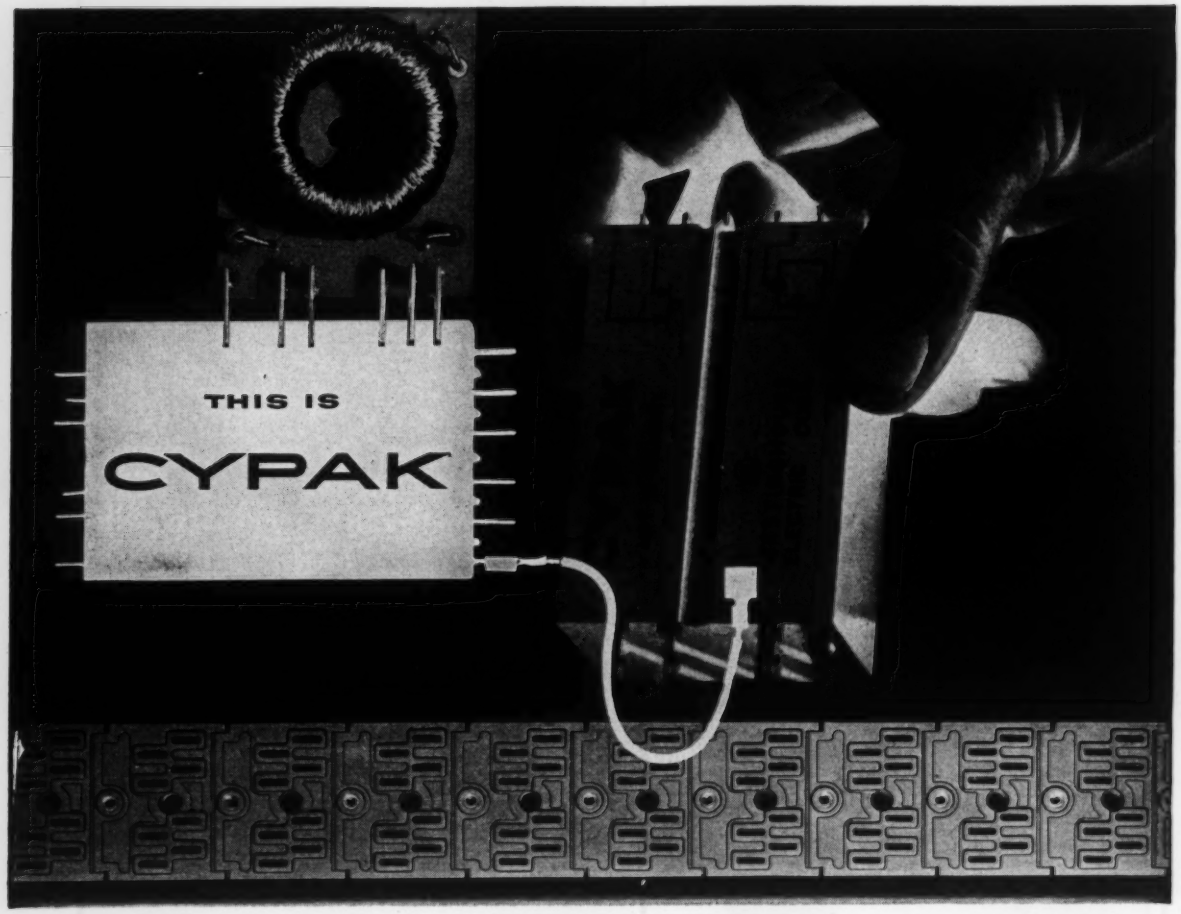
Rubber Lined and Covered Equipment

Sintered Metal Friction Elements

Asbestos Textiles

Teflon Tape, Packings, Sheets, Rods, Tubes

Engineered Molded Rubber and Plastics



for industrial control 15 times more reliable

With CYPAK* control you can introduce a whole new concept of reliability for industrial systems. Unlike the mechanical relay, CYPAK has *no* moving parts. While twenty million open-close cycles is usually the maximum life of a mechanical relay, CYPAK systems can handle that many cycles in days, without a trace of fatigue. Down time due to wear, corrosion, or jamming no longer throws a block to expanding control system responsibility.

One reason for CYPAK dependability is Westinghouse Hipernik* V magnetic steel. In toroidal coils, this high-grade steel produces sharp current amplification to parallel the mechanical relay step function. These important magnetic characteristics are completely protected by sealing each CYPAK component panel in a solid plastic block.

Look into all the new opportunities in CYPAK by calling your Westinghouse sales engineer today. J-01003

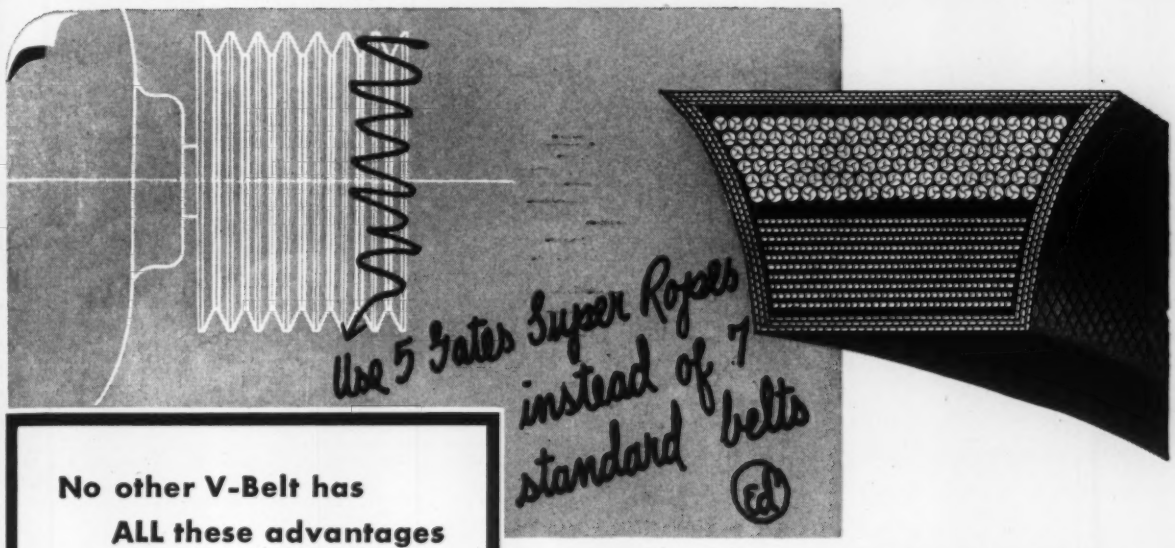
*Trademark

Write today for your free copy of *The Whys and Wherefores of* CYPAK, Booklet B-6584. Westinghouse Electric Corporation, 3 Gateway Center, P. O. Box 868, Pittsburgh 30, Pennsylvania.

WATCH WESTINGHOUSE

WHERE THE FUTURE IS ALREADY IN PRODUCTION!

Get more HP delivered per $ of drive cost



No other V-Belt has ALL these advantages

1. Tough, resilient Tensile Cords

Super-strength tensile cords provide 40% greater horsepower capacity . . . easily absorb heavy shock loads . . . reduce number of belts required . . . save weight and space.

2. Concave Sidewalls (U.S. Pat. 1813698)

Concave sides (Fig. 1) increase belt life. As belt bends, concave sidewalls become straight, making uniform contact with sheave groove (Fig. 1-A). Uniform contact means less wear on sides of belt . . . far longer belt life.

3. Flex-Weave Cover (U.S. Pat. 2519590)

A Gates exclusive provides greater flexibility with far less stress on fabric. Cover wears longer . . . increases belt life . . . more power available to driven machine.

4. High Electrical Conductivity

Built into Gates Super Vulco Ropes for safer drives (in explosive atmospheres).

5. Oil, Heat, Weather Resistant

Special rubber compounds make Super Vulco Ropes highly resistant to heat, oil, and prolonged exposure.

Cut sheave width and weight with Gates Super Vulco Ropes

You save on cost of iron . . . you reduce bearing width and support . . . you save space and overall cost . . . when you design a drive using Gates Super Vulco Ropes. Here's why:

5 Gates Super Vulco Ropes do the work of 7 standard V-belts

That's because Gates Super V-Belt has 40% more horsepower capacity than standard belts. Therefore, you can reduce sheave width and weight . . . cut cost.

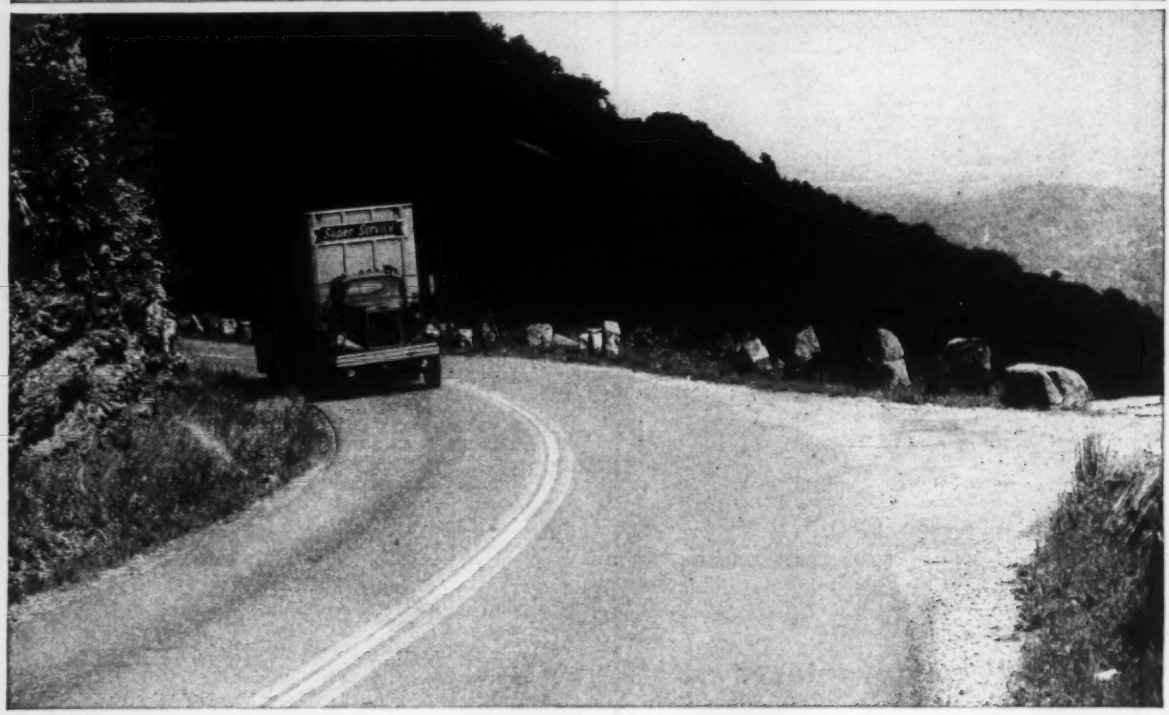
A wealth of drive data is quickly available to you. Simply call your nearby Gates V-Belt Distributor (see 'phone book yellow pages) for a Gates V-Belt specialist. Stocks available in industrial centers around the world. The Gates Rubber Co., Denver, Colorado—*World's Largest Maker of V-Belts.*

The Mark of Gates Specialized Research

TPA 91

Gates Super VULCO ROPE Drives

TRUCKING . . . Vital Transportation Link



Transmission Repairs only .0003c (3/10 mill) per mile at SUPER SERVICE

after an average of 210,176 miles on each of 172 Fuller Transmissions

"With the Fuller ROADRANGERS in our fleet, we've hit an all-time low in transmission repair costs," says Ray Carter, Director of Engineering for Super Service Motor Freight Co., Nashville, Tennessee.

Super Service recently completed a careful check of maintenance records for 172 White tractors equipped with Fuller 10-speed Semi-Automatic ROADRANGER Transmissions. With an average of 210,176 miles per tractor, company records showed a remarkable average repair cost of *only .0003c (3/10 of a mill) per mile for each* ROADRANGER *Transmission!*

About two years ago, Super Service standardized its entire over-the-road fleet on White tractors equipped with ROADRANGER Transmissions and Cummins diesel engines. From that time on, old performance records began to fall.

Operating from the South to the East . . . with terminals from Nashville to New York . . . the ROADRANGER equipped tractors pull square nose, 35-foot aluminum trailers that average 52,500 lbs. gross tare weight. The tractors now cut a full hour off the old 10-hour trip time on the Nashville-East run . . . taking rugged Tennessee hills at 35 miles an hour when 15 was considered a good speed with the old equipment.

Super Service cuts running time and maintenance to a minimum by running its rigs straight through from Nashville to New York. Drivers are changed twice . . . but there's no need to warm up a cold engine at each stage of the relay.

For your fleet, get the facts on ROADRANGERS from your truck manufacturer or truck dealer now.

FULLER MANUFACTURING COMPANY
TRANSMISSION DIVISION • KALAMAZOO, MICH.

Unit Drop Forge Div., Milwaukee 1, Wis. • Shuler Axle Co., Louisville, Ky. (Subsidiary) • Sales & Service, All Products, West. Dist. Branch, Oakland 6, Cal. and Southwest Dist. Office, Tulsa 3, Okla.

using

DU PONT ELASTOMERS

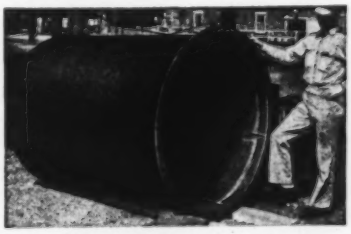
NEOPRENE—HYPALON®

4 in Design

HYPALON® tank linings for strong oxidizing agents

Now a wide range of chemicals can be safely handled by storage tanks and shipping containers for long periods. The secret is a lining made of HYPALON, Du Pont's new synthetic rubber. Tank linings of HYPALON have extra-high resistance to chemicals—even the strongest oxidizing agents have little effect on linings of HYPALON.

But exceptional chemical resistance is just part of the story: HYPALON also withstands temperatures from 250°F. to 350°F. It is *completely unaffected* by ozone and can take prolonged exposure to weathering and sunlight without deteriorating.



TANK LINED with HYPALON for storage of calcium hypochlorite. HYPALON is applied by standard lining methods, adheres firmly.

HYPALON can provide extra-high durability to products exposed to severe service conditions; such as hose for handling strong acids and hot fluids; gaskets and packings in high-temperature service; protective coatings for metal and masonry; and many others. To become acquainted with Du Pont HYPALON—just clip and mail coupon.

Circle 540 on page 19

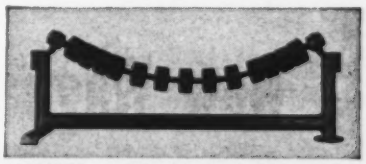
Flexible NEOPRENE idlers for conveyor belts outlast steel idlers better than 8 to 1

NEOPRENE IDLERS are still in service after two years. Accumulated sand previously fouled the steel idler bearings, stopped the idlers and damaged the belt. Average service was three months.

NEOPRENE resists abrasive action of sand, retains its flexibility

At one point in the production of castings at a magnesium foundry in the Midwest a conveyor belt carries molding sand from a chute up a 35° incline to another belt. Sand builds up under the belt. When the belt ran on steel idlers, sand fouled the bearings, jammed the idlers and damaged the belt. Average service life of the steel idlers was three months.

The manufacturer decided to install flexible idlers made of neoprene. The new idlers, developed by Joy Manufacturing Company, consist of neoprene discs permanently bonded to a flexible neoprene-sheathed steel cable and suspended from a single sealed bearing at each end. These end bearings are up out of the sand so spillage does not affect them. The discs supporting the belt, being flexible, conform to the shape of irregular loads, reducing loss of material through spillage. The idlers clean themselves because constant flexing forces the sand from



NEW IDLERS consist of resilient neoprene discs permanently bonded to a flexible neoprene-sheathed steel cable which is suspended from a single sealed bearing at each end.

between the rotating discs. Neoprene was the natural choice for this use because of its lasting resilience and resistance to the abrasive action of the sand. After two years—*more than eight times the service life of the steel idlers*—the neoprene idlers are still on the job.

Specify neoprene in the rubber products you design. Of all general-purpose elastomers, only neoprene possesses a *balanced combination of properties*. For further information on designing new or improved products with neoprene clip and mail the coupon below.

DU PONT
REG. U.S. PAT. OFF.

HYPALON *is a registered trademark of E.I. du Pont de Nemours & Co. (Inc.)*

BETTER THINGS FOR BETTER LIVING . . . *THROUGH CHEMISTRY*

Please send further literature and add my name to the mailing list for your free publications, the "Neoprene Notebook" and "Facts about HYPALON®," which show how the Du Pont elastomers are used in designing new products, improving old.

E. I. du Pont de Nemours & Co. (Inc.)
Elastomers Division, Dept. MD-11
Wilmington 98, Delaware

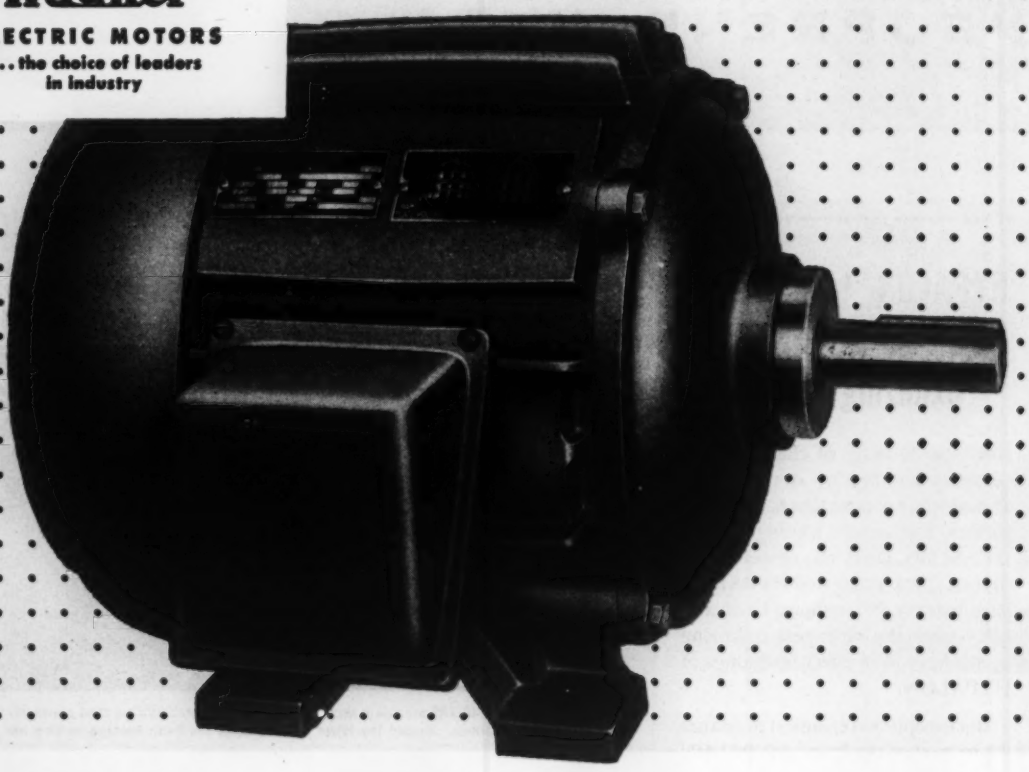
Name_____ **Position**_____

Firm_____

Address_____

City_____ State_____

Wagner®
ELECTRIC MOTORS
...the choice of leaders in industry



New Wagner totally-enclosed motors mean

These new Wagner totally-enclosed fan-cooled motors are particularly suitable for use on all types of machine drives.

They are fully protected against damage from steel filings, chips, dust, dirt, fumes and moisture. They require no maintenance other than periodic lubrication.

If appearance is a factor, you'll find that the pleasing proportions of these motors give them that functional beauty obtained only when the design is fundamentally *right*. Ribs on the corrosion-resistant cast iron frames add mechanical strength and increase the surface area for more efficient cooling. Full information is given in Bulletin MU-203, which is yours for the asking.

Your nearby Wagner engineer can help you select the right motor for your application. Call the nearest of our 32 branch offices, or write us.

Wagner Electric Corporation
EST. 1891

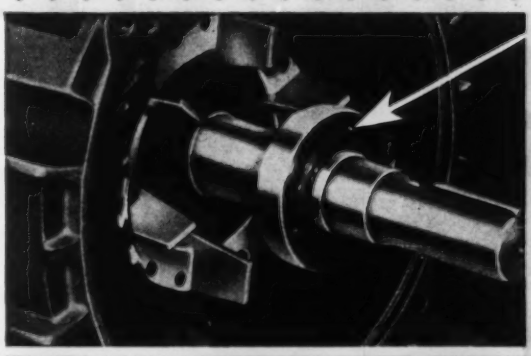
WAGNER ELECTRIC CORPORATION
6404 Plymouth Ave. • St. Louis 14, Mo., U. S. A.

ELECTRIC MOTORS • TRANSFORMERS • INDUSTRIAL BRAKES
AUTOMOTIVE BRAKE SYSTEMS — Air and hydraulic

BRANCHES IN 32 PRINCIPAL CITIES

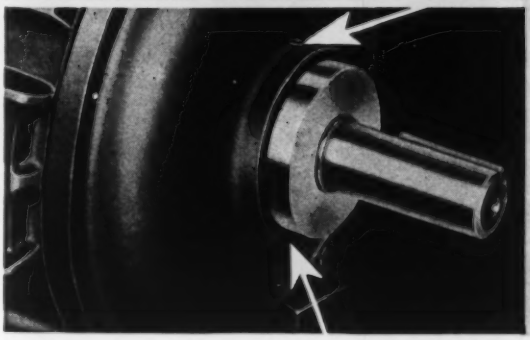
HEAVY-DUTY BALL BEARINGS

Highest quality bearings of more than ample capacity to carry heavy loads provide long troublefree service.



BEARINGS CAN BE RE-LUBRICATED

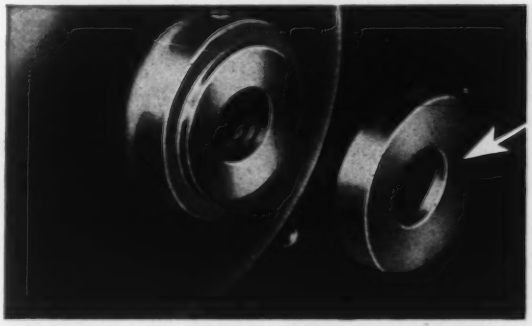
Wagner motors can be re-lubricated when necessary to prolong bearing life. New grease can be added — old grease removed through openings provided in top and bottom of bearing housing.



less down-time for machine drives

BEARINGS STAY CLEAN

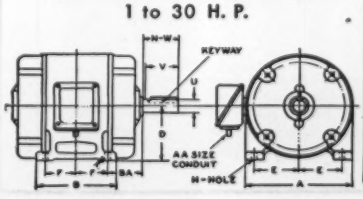
Both ends of these motors are equipped with running shaft seals to keep dust, dirt and water from the bearings. There's no grease loss because bearing housings have effective seals to prevent escape of grease.



M56-15

BUILT IN NEMA FRAME SIZES—182 THROUGH 326U

FRAME SIZES AND DIMENSIONS
1 to 30 H. P.



HP	Frame No.	Key			A max.	B max.	D	E	F	BA	H	N-W	U	V min.	AA min. size of cond't
		Width	Thick-ness	Length											
1	182	3/16	3/16	1 3/8	9	6 1/2	4 1/2	3 3/4	2 1/4	2 3/4	13/32	2 1/4	7/8	2	3/4
1 1/2	184	3/16	3/16	1 3/8	9	7 1/2	4 1/2	3 3/4	2 3/4	2 3/4	13/32	2 1/4	7/8	2	3/4
2	184	3/16	3/16	1 3/8	9	7 1/2	4 1/2	3 3/4	2 3/4	2 3/4	13/32	2 1/4	7/8	2	3/4
3	213	1/4	1/4	2	10 1/2	7 1/2	5 1/4	4 1/4	2 3/4	3 1/2	13/32	3	1 1/8	2 3/4	3/4
5	215	1/4	1/4	2	10 1/2	9	5 1/4	4 1/4	3 1/2	3 1/2	13/32	3	1 1/8	2 3/4	3/4
7 1/2	254U	5/16	5/16	2 3/4	12 1/2	10 3/4	6 1/4	5	4 1/8	4 1/4	17/32	3 3/4	1 3/8	3 1/2	1
10	256U	5/16	5/16	2 3/4	12 1/2	12 1/2	6 1/4	5	5	4 1/4	17/32	3 3/4	1 3/8	3 1/2	1
15	284U	3/8	3/8	3 3/4	14	12 1/2	7	5 1/2	4 3/4	4 3/4	17/32	4 7/8	1 3/8	4 3/8	1 1/4
20	286U	3/8	3/8	3 3/4	14	14	7	5 1/2	5 1/2	4 3/4	17/32	4 7/8	1 3/8	4 3/8	1 1/4
25	324U	1/2	1/2	4 1/4	16	14	8	6 1/4	5 1/4	5 1/4	21/32	5 3/8	1 7/8	5 3/8	1 1/2
30	326U	1/2	1/2	4 1/4	16	15 1/2	8	6 1/4	6	5 1/4	21/32	5 3/8	1 7/8	5 3/8	1 1/2

Circle 541 on page 19

VERSATILE

MECHANICS Roller Bearing UNIVERSAL JOINTS excell for both main drives and controls — in all kinds of material handling trucks Have transmission flanges for any type of brake drum Easy to service — MECHANICS Close-Coupled UNIVERSAL JOINTS transmit more power — in less space — at greater angles than any other joints. Let MECHANICS engineers help give *your* machines competitive advantages.

MECHANICS UNIVERSAL JOINT DIVISION
Borg-Warner • 2032 Harrison Ave., Rockford, Ill.
Export Sales: Borg-Warner International
36 So. Wabash, Chicago 3, Illinois

MECHANICS
Roller Bearing B-W
UNIVERSAL JOINTS

For Cars • Trucks • Tractors • Farm Implements • Road Machinery • Aircraft • Tanks • Busses and Industrial Equipment

Circle 542 on page 19
Circle 543 on page 19→

ALCOA'S UP-TO-DATER ON CASTINGS

Four new-development pages on super-strength impellers, uniform-wall castings, unusual permanent-mold castings, new high-strength alloys, and other meaty data for today's smart young men who will be supervisors tomorrow.

meaty data for today's smart young men

"Close Tolerances"—a Misnomer?

Precision, or close tolerance, casting saves a bundle on jobs that used to require much expensive machining. "Close tolerances" and "smooth finishes" are loosely used phrases. They mean anything tighter than the old sand foundry standard of ± 1/32″ and 500 micro-inches.

At Alcoa, by using plaster-mold processes, tolerances of 0.005″ are possible on certain jobs. Pattern smoothness and close tolerances are easily reproduced since the mold starts as a slurry of gypsum. And plaster molding is often combined with sand-and-iron molding to produce amazing castings.

Plaster molding, and its ability to be combined with other methods, add a new tool to the designer's toolbox. We'd like to explore the possibilities with you.

Sand casting, however, is still far from over the hill. It still is the cheapest method for a short run and certainly a widely used process at Alcoa. Occasionally, on certain small items we use match plate techniques and high-speed molding machines to knock them out faster and cheaper in sand than we can do in die castings or permanent-mold castings. Our sand castings run from a few ounces all the way up to a diesel engine cylinder block, 9′ x 6′ x 6′, weighing 7450 pounds.

Most Uniform Walls Ever Cast

Plaster castings with wall thicknesses down to .060″ are now being made at Alcoa. Tolerances are ± .005″ wall thickness. Right now, they're air scoops for the aircraft industry, made in both rounds and rectangles up to about 25″ long. Curved shapes present no problems. The process is more expensive but worth it because it cuts the weight of an air scoop in half. If your problem is thin, uniform walls, we'd like to explore the possibilities with you.

hopped on the new alloy band wagon to replace expensively machined and fabricated wrought parts

What Is a "Large Permanent-Mold Casting"?

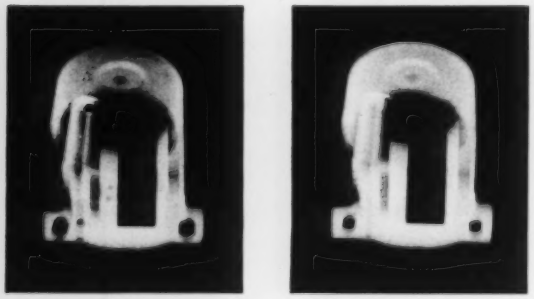
Not so long ago, permanent-mold castings larger than 12 inches and 2 or 3 pounds were rare as dodoes. Now we cast a cylinder of 800 pounds, 36 inches high, 30 inches diameter with 4-inch walls in permanent molds. The part is a rolling mill bearing. Others include engine pistons of 250 pounds, compressor cases for jets of 150 pounds.

We're now casting the entire bumper of a 1957 automobile . . . a routine permanent-mold job. These 28-pound castings are not only large but also are made in large quantities.

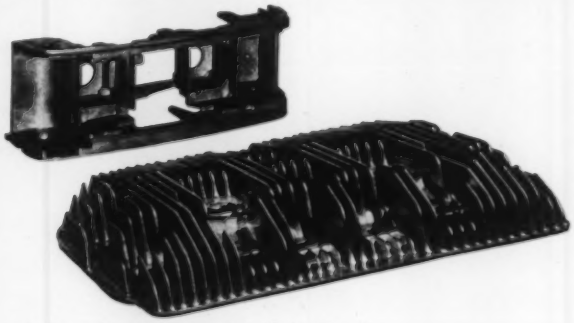
More than one designer has made himself a hero to his boss by looking into permanent-mold castings. Smooth and clean surfaces, medium-to-long production runs, tolerances of $\frac{1}{64}$″ plus .002″ per inch (although $\frac{1}{32}$″ in 5 feet has been made), good mechanical properties and modest complexity usually indicate permanent-mold castings.

Super-Strength and High-Speed Impellers

Imagine an impeller, 9½″ diameter, spinning at 60,000 rpm. Peripheral tip-speed tops 2500 ft. per second, 1800 mph. That's a casting recently turned out by a radical new manufacturing technique. Another impeller, to operate at 58,000 rpm, has delicate curved blades with the as-cast leading edges tapering to .020″. These two examples are used for turbo-charging and weigh 3 or 4 pounds. Other super-strength impellers for industrial refrigeration weigh 400 lbs. This new process gives properties as high as 50,000 psi tensile, 35,000 psi yield, 5% elongation.



High-Density Process — At left, X-ray photo of casting made by conventional die-casting method. At right, X-ray print of same part cast by Alcoa's new high-density process — porosity virtually eliminated.



Complex Die Casting — Cylinder head and camera frame are interesting examples of modern Alcoa Die Castings.

Cost-reduction note: The super-strength process can be combined with ordinary *cast* properties in the same part and at substantial savings.

Die Castings—Greater Use and Growing Size

Just a few years ago, aluminum die castings were used mostly as shrouds or covers. Now they're used for many structural parts. Reason: As labor rates have gone up, so has the use of die castings —to save assembly and machining costs. New alloys have given aluminum die castings greater strength and ductility: For air-conditioning compressor parts, automotive transmissions, vacuum cleaners, cylinder heads, etc. Alloys with high endurance limits are responsible for the increasing use of die castings in highly stressed reciprocating parts. As to size, office chair swivel bases and rotary lawn mower enclosures are now being die-cast at Alcoa.

high-density method for small, chunky parts

Alcoa has developed a high-density casting method for small chunky parts. Now soundness approximating wrought materials is possible as examination of the accompanying X-ray photos shows.

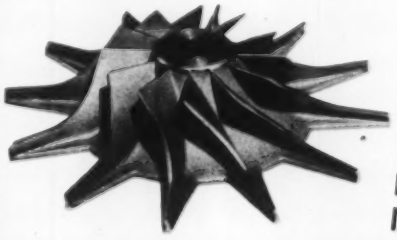
Need High-Strength Alloys? Here Are Three New Problem Solvers

Perhaps the toughest nut to crack in designing an aluminum casting is to pick the right alloy. That is, if you go it alone. Alcoa has over 40 standard casting alloys and each one is designed for a specific use. Your Alcoa representative is an authority on alloys. Use him.

Several of the most recent alloys are worthy of special note: Two are alloys C355 and A356 *for permanent-mold work*. Being high-purity variations of the familiar 355 and 356, they require careful foundry handling but develop extremely high levels of strength and ductility. Shown, on the next page, are the properties for permanent-mold cast test bars for these new alloys in two tempers.

more than one designer has made himself a hero to his boss with permanent-mold castings

Super-Strength Impeller — Diesel engine turbocharger impeller spins at 58,000 rpm. Edges taper to air cleaving .020". Plaster-casting process.



Large Permanent-Mold Casting — Rolling mill bearing goes 800 lbs., 3 ft. high, 2½ ft. diameter, 4 in. walls.

Uniform Walls — Plaster-cast air scoop includes walls with thicknesses of .060", with wall tolerances of .005".

Mechanical Properties

In the die-casting field, alloy X364 is going to increase applications where strength in highly stressed parts is important. Its properties are roughly equal to those of alloy 218, but it's easier to cast and therefore cheaper. Its price will be slightly higher than 380 and 360 alloys so it shouldn't be specified as a replacement for those alloys unless higher strength, better elongation and impact resistance are needed. Shown is a chart giving typical properties (obtained with die-cast ¼" test bars) of this experimental alloy X364, as compared with 218, 360 and 380 alloys.

	Guaranteed Minimum			Typical		
Alloy & Temper	Tensile psi	Yield psi	Elong. %	Tensile psi	Yield psi	Elong. psi
C355-T61	40,000	30,000	3.0	46,000	34,000	6.0
C355-T62	47,000	40,000	1.5	52,000	44,000	4.0
A356-T6	32,000	18,000	10.5	37,000	22,000	15.0
A356-T61	37,000	26,000	5.0	41,000	30,000	10.0

Alloy	Temper	Tensile Strength-psi	Yield Strength-psi	Elongation %
X364	—F	41,000	22,000	7.5
X364	—T5	46,000	33,000	4.0
218	—F	45,000	27,000	8.0
360	—F	44,000	27,000	3.0
380	—F	43,000	26,000	2.0

Right now the ones who have hopped on the C355, X364 and A356 alloy band wagon are designers who are using these alloys to replace wrought structures which involved expensive machining and fabrication. But we expect real interest from designers faced with any part subject to impact. Stir up any ideas?

when a designer needs three eyes:
for costs, competition and performance

Straight Talk

In these days, when a designer needs three eyes, one for costs, one for competition and one for performance, he has often found the answer to all three problems in Alcoa® Castings. Many times, the solid technical help contributed by the Alcoa sales engineers and casting specialists has either cut costs or improved performance. And, *because Alcoa offers all casting processes their recommendations are completely unbiased.*

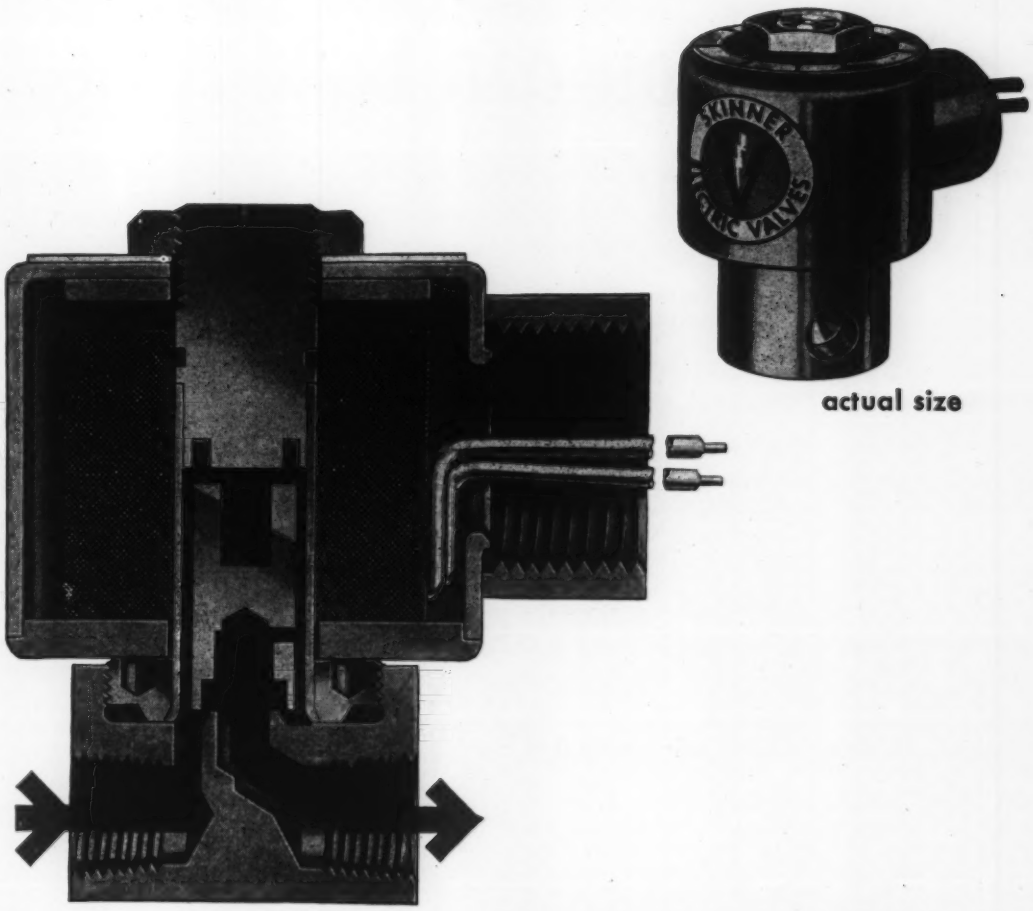
The nicest thing about this help is that it's free and waiting at your local Alcoa office, listed under "Aluminum" in your classified phone book. Better yet, write for your copy of Alcoa's new technical book, *Alcoa Aluminum Handbook*, 176 pages, 140 tables. ALUMINUM COMPANY OF AMERICA, 1994-M Alcoa Building, Pittsburgh 19, Pennsylvania.

Your Guide to the Best in Aluminum Value

ALCOA ALUMINUM CASTINGS

ALUMINUM COMPANY OF AMERICA

Litho in U.S.A.



actual size

New C-series solenoid valve offers recognized "Skinner Quality" at low cost

This is a faithful reproduction – in miniature – of the time-tested, 2-way, normally closed Skinner V5 except that the body is made of brass.

This new, compact Skinner valve weighs only 12 ounces, yet it's rugged enough to last millions of cycles on most applications. It is a packless, direct-acting valve with only two moving parts. And it's absolutely bubbletight – even on vacuum. This C-Series Skinner valve is failproof, too – positive closing is assured by a spring return. It can be mounted in any position and is ideal for direct-line mounting.

You'll find this new valve, with its recognized "Skinner Quality," the perfect low-cost answer to a wide range of flow control problems. It works efficiently with air, water, oils, gasoline and many other media. Typical applications include: automotive fuel systems, welding equipment, vending machines, lubricating devices, spraying equipment, air horns, water softeners, humidifiers and instrumentation.

Our Bulletin D11.1 contains complete information on this valve – flow curves, optional features, dimensions, electrical data, etc. We will be happy to send you a copy on request.

SKINNER · ELECTRIC VALVES ·

SKINNER ELECTRIC VALVE DIVISION
NEW BRITAIN CONNECTICUT
THE SKINNER CHUCK COMPANY

Circle 544 on page 19

You can build it better

BUILT TO LAST. Light in weight, strong and tough, highly resistant to corrosion and abrasion, the 40-ft. hull of this attractive houseboat, built of 12-ga. USS COR-TEN Steel, has what it takes to give long years of low-maintenance, trouble-free service. Customarily beached by being run right up on the shore, this boat needs COR-TEN Steel's superior strength and high resistance to wear and impact to withstand such rough usage. Says the owner, "Despite the fact that on five different occasions the boat has been dropped from the dry-dock from heights ranging from 6 to 12 feet—treatment that would have completely wrecked a boat of usual construction —the 5½-year-old hull is still in excellent condition and appears good for many, many more years." (This all-steel boat was constructed by Kelly Shop, Inc., Jeffersonville, Ind.)

• • •

USS COR-TEN Steel has been approved by the American Bureau of Shipping for use in hull construction, either riveted or welded, with a general reduction from mild steel weights or sections of about 10 per cent. Lloyds Register of Shipping has stated that COR-TEN Steel is acceptable under its rules as a special quality steel for ship building. Its use in oil tankers, ore boats, dredges, barges and pleasure craft, both in fresh and salt water service during the past 23 years, has definitely proved USS COR-TEN Steel s exceptional fitness for marine construction.

with USS High Strength Steels

In USS High Strength Steels, design engineers have at their command three service-tested steels that will permit them to materially increase the efficiency and economy of machinery, equipment and structures at little or no increase in first cost . . . and frequently at less cost.

All three of these famous *"steels that do more"*—USS Cor-Ten, USS Man-Ten and USS Tri-Ten "E"—have a 50% higher yield point than plain carbon steel. All have better atmospheric corrosion resistance and offer greater resistance to wear, fatigue and impact. Each, however, has specific superior properties that should be considered in determining its selection.

USS Cor-Ten Steel, for example, is distinguished by its superior resistance to atmospheric corrosion—4 to 6 times that of carbon steel. USS Man-Ten Steel is intended for weight reduction by means of greater strength in moderate forming applications, with enhanced resistance to abrasion and atmospheric corrosion. USS Tri-Ten "E" Steel's outstanding characteristics are excellent weldability and resistance to shock.

Used singly or in combination, these steels can advantageously replace carbon steel to increase the strength and durability of vital parts *without* increasing their weight. Or when the use of thinner sections is feasible, they can (1) reduce equipment weight without reducing its strength, or (2) increase the size and capacity of equipment without increasing total weight or the power required to move it.

• • •

You will find our 174-page *"Design Manual for High Strength Steels"* extremely useful in applying the benefits of these steels to your product. Send for free copy—simply write on your company letterhead to United States Steel Corporation, Room 2801, 525 William Penn Place, Pittsburgh 30, Pa.

"PREGNANT PLATYPUS." That's what the designers call this new combination trailer made to carry two completely unrelated types of products. Going in one direction it hauls 800 gals. of glue in the "dromedary" tank and 4,000 gals. in the belly tank below the trailer. On the return trip it carries 42,000 lbs. of plywood in the trailer van. To reduce empty weight and obtain greater strength—and at the same time to provide resistance to the mildly corrosive glue carried—USS Cor-Ten Steel was used in both tanks and in the trailer frame, body framing and cross frame members as well. As a result, the unit weighs 1,800 lbs. (11½%) *less* than if mild steel had been used, and will carry maximum payload, require less maintenance and last longer. Built by Peerless Trailer and Truck Service, Portland, Ore., for M and M Wood Working Company.

TO BEAT HEAT AND ABRASION. This asphalt mixing plant produces tar or asphalt road-paving mixes at a rate of more than 60 tons per hour. In the dryer, which removes the moisture from the sand and stone in the aggregate, temperatures run as high as 800° F. Abrasive action is severe.

To meet these conditions the Barber-Greene Co. of Aurora, Ill., builds the entire dryer drum (circle) of USS Man-Ten Steel. In this way they obtain one and a half times greater yield point than with carbon steel, greater abrasion resistance, and greater resistance to heat, impact and vibration. These qualities pay off by keeping the equipment more continuously on the job.

UNITED STATES STEEL CORPORATION, PITTSBURGH • AMERICAN STEEL & WIRE DIVISION, CLEVELAND
COLUMBIA-GENEVA STEEL DIVISION, SAN FRANCISCO • NATIONAL TUBE DIVISION, PITTSBURGH
TENNESSEE COAL & IRON DIVISION, FAIRFIELD, ALA. • UNITED STATES STEEL SUPPLY DIVISION, WAREHOUSE DISTRIBUTORS
UNITED STATES STEEL EXPORT COMPANY, NEW YORK

USS HIGH STRENGTH STEELS

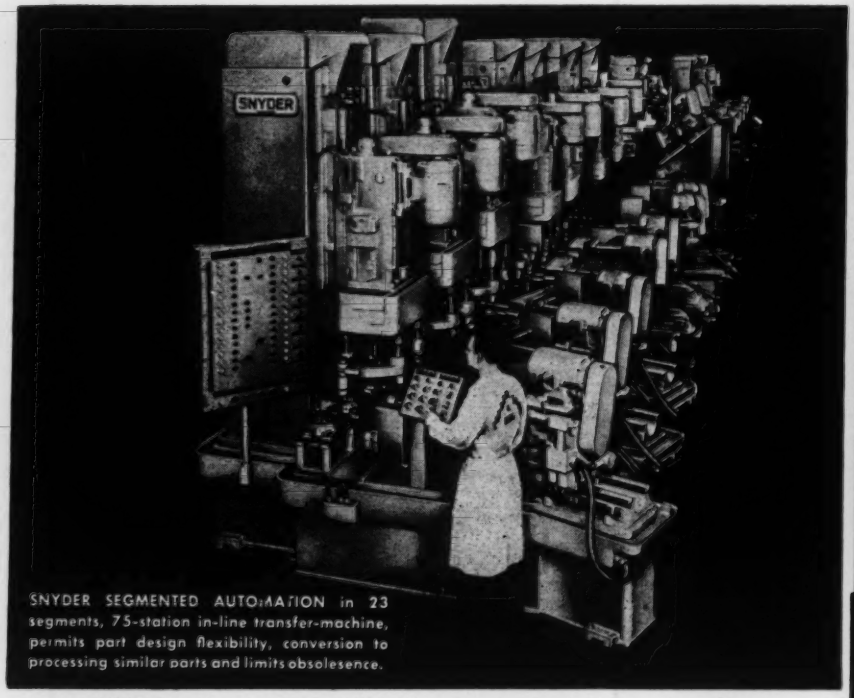
USS MAN-TEN • USS COR-TEN • USS TRI-TEN

1933 UNITED STATES STEEL USS HIGH STRENGTH STEELS 1956
23 YEARS OF PERFORMANCE

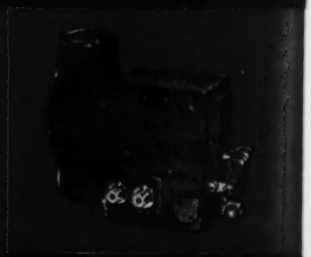
UNITED STATES STEEL

Circle 545 on page 19

PROCESSING 144 PIECES PER HOUR AT 80% EFFICIENCY!



SNYDER SEGMENTED AUTOMATION in 23 segments, 75-station in-line transfer-machine, permits part design flexibility, conversion to processing similar parts and limits obsolesence.



DUAL FEED PANEL—Solenoid operated directional control and cam operated feed selector. Provides rapid traverse forward, two adjustable forward feed rates, rapid return. Smaller solenoids used with lower current requirements. Operation is smoother, units more compact in size.

SOLENOID CONTROLLED pilot operated 4 way. Solenoids control shifting to two extreme positions. Shifted to center by spring when solenoids are de-energized. 12 spool types and integral pilot pressure device eliminates need for external piloting.

This Snyder Automatic drills, reams, spot-faces, chamfers, bores, counterbores, mills, taps, and automatically air-gages work on automatic transmission front oil-pump bodies at 144 pieces an hour at 80% efficiency.

Double A Valves stand up under grueling production loads because they are made sturdily to do just that! And a wide range of optional features (unique in the industry!) means you cannot fail to select the right valve setup for efficient application to a specific job! Users find Double A's personal technical assistance of *major importance* also...helps with valve selection, circuits...service calls on unusually short notice!

Write for **BULLETIN NO. 551**

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Phone: Worth 4-3580

CORNING GLASS BULLETIN

FOR PRODUCT DESIGNERS

(Advertisement)

Microwaves in the kitchen

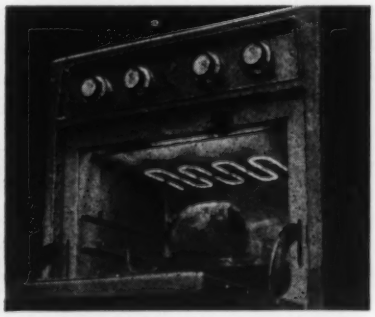
Tappan's latest electronic range lets you cook a 5-pound roast in 30 minutes, bake a potato in 4, broil bacon in 1½, heat a jar of baby food in 45 seconds.

Key to this microwave magic is a magnetron supplied by Raytheon. It generates waves of 2450 megacycles, a frequency that requires licensing by the Federal Communications Commission.

These waves do the cooking. They are fed into the oven cavity by a guide mounted at the top and properly diffused by a slowly revolving fan and a sheet of glass.

This glass, as you might imagine, is no ordinary piece of window pane. It has to pass the high-frequency waves and help in their even distribution. It also must protect the electronic elements and fan from hot, spattering grease.

Handling the task nicely is Corning's VYCOR brand glass No. 7900, one of a group of 96% silica glasses exhibiting some quite unusual performance characteristics.



Tubing below VYCOR glass shield (arrow) is an infrared unit to give a pleasant "browning" effect to food.

For example, you can heat an object made of No. 7900 glass to 900° C., then plunge it into ice water. You'll get *no* cracking, crazing, breaking, or changing in shape or structure even after such terrific thermal shocks.

Continuous use at 900° C. is standard operation; and intermittent use to 1200° C. is both possible and practical.

VYCOR brand glass also does a fine job of transmitting ultraviolet at wave lengths of 365 millimicrons and higher, and short-wave infrared up to 3.5 microns.

Details on seven of the VYCOR brand glasses (including facts on manufacturing, physical properties, uses and forms) are summed up in B-91: "VYCOR brand Industrial Glassware by Corning." A copy awaits your request.

Lachrymal lesson

Legend has it that ancient Romans grieving their departed collected their tears in small vases and buried the vases with the deceased.

Such vases go back to the Rome of about 300 A.D. Yet, despite this antiquity, so many are *still* in such perfect shape that a tourist can own one for the outlay of a mere 50 cents.

Lesson? Oh, yes, —these long-lasting vessels for lachrymal liquid were made of *glass*. And glass, as made *today*, offers the designer a host of useful qualities, in addition to durability.

Take as a starter, PYREX brand glass No. 7740. It's the choice of those whose products must cope with corrosive environments, thermal shock, and rough handling in general.

Among the literally thousands of useful items fashioned from this particular Corning glass you'll find precision labware; piping for the food, chemical and drug industries; broiler shields; oven windows; oven cooking ware; dental and medical products; vapor chambers; coffee makers and servers; and sundry lamp globes.

No. 7740 is just *one* of a wide array of glasses by Corning available in commercial quantities . . . which brings us to a standing offer:

You can tap the data files on some 50,000-odd formulas for glass in quest of an answer to your materials problems. What we've learned about the advantages (and limitations) of glass we'd like to share with you.

Or, if more background data on what you can do with today's *engineered* glasses seems in order, send for any or all of the free literature listed in the coupon.

Look, no gasket!

Troubles—that's what most of us have come to expect with sight glasses used in pipelines or other strategic locations.

Causes are not hard to pinpoint—innocent tampering, heat and vibration that cause failure in soldered joints, various forces that result in gaskets degenerating.

'Til now most of us have quietly accepted the inevitable disruptions. But, there's no need to any longer.

Working with a prominent supplier of refrigeration equipment, we've come up with a real innovation—a gasketless, solderless, sight-glass assembly.

Glass fused directly to metal provides unusually rugged service in these sight glass assemblies.

In this new Corning development, the glass and metal are fused directly together. Result? A hermetically-sealed, tamperproof arrangement that stands up to moderate heats and high pressures.

A number of variations are available, with diameters ranging from $\frac{3}{16}$" to 1", with glasses from $\frac{1}{16}$" to ¼" thick.

Typical performance—⅜" diameter and a ⅛"-thick glass withstood pressures in excess of 5,000 p.s.i.

If you need to see what goes on in a closed system, why not look into these windows?

Corning means research in Glass

CORNING GLASS WORKS, 52-11 Crystal Street, Corning, N. Y.

Please send me the following material: Bulletin B-91, "VYCOR brand Industrial Glassware by Corning" ☐; Bulletin IZ-1, "Glass . . . its increasing importance in product design" ☐; Bulletin B-84, "Manufacturing and Design of Commercial Glass" ☐; Illustrated booklet, "Glass and You" ☐; Information on sight glasses ☐.

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Company_____

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City_____ Zone____ State_____

Circle 547 on page 19

★ Control Components Digest ★

News and notes on resistors, rheostats, relays, motor controls, dimmers and other control components

NEW! MINIATURE RESISTOR for MINIATURE EQUIPMENT

New Ward Leonard 3-watt wirewound fills need for high-stability, space-saving power resistor

NEW WARD LEONARD TYPE 3X Resistor

A 3-watt wirewound with the compactness of an ordinary ½-watt composition resistor—that's what Ward Leonard's new Type 3X Axiohm resistor gives you!

This new resistor now makes it practical to specify a wirewound resistor for your transistorized, printed-circuit, or other miniaturized designs. You get the wirewound resistor's drift-free stability, low voltage coefficient, and high overload capacity in a tiny package.

Type 3X Axiohms, like larger Ward Leonard Axiohm resistors, are wound with special alloy resistance wire on tough miniature ceramic cores. Temperature coefficient of resistance is exceptionally low.

Resistance wire and axial leads are spot-welded to end caps, insuring a strong, permanent, low-resistance bond.

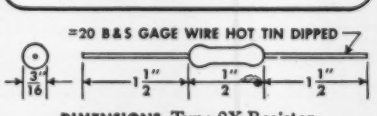
The entire resistor assembly is encased in Vitrohm enamel forming a hard, crazeless, heat-conducting hermetic seal. Leads are tin-dipped for fast soldering. No mounting hardware is required. Conservative 3-watt rating is based on 300°C rise, 40°C ambient.

Order these resistors by type number (3X) and resistance value (see table at right).

STOCK VALUES, TYPE 3X

Value* (Ohms)	Current (ma)	Value* (Ohms)	Current (ma)
1	1732	400	87
1.5	1413	450	82
2	1226	500	78
3	1000	600	71
4	866	700	66
5	776	750	63
7.5	632	800	61
10	548	900	58
12	500	1000	55
15	447	1100	52
20	387	1200	50
25	346	1250	49
30	316	1500	45
35	293	1750	42
40	274	2000	39
50	245	2250	36
75	200	2500	35
100	173	3000	32
125	155	3500	29
150	141	4000	27
200	123	4500	26
225	116	5000	25
250	110	6000	22
300	100	6500	21
350	93	....	..

Resistance tolerance ± 5 percent

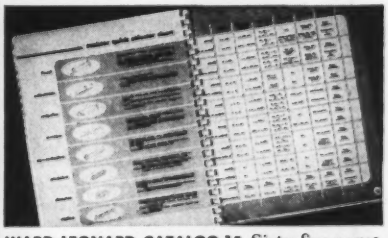


DIMENSIONS, Type 3X Resistor

You can still get 5- and 10-watt Ward Leonard miniatures

Ward Leonard 5- and 10-watt Axiohms have proved themselves in business machines, guided missiles, computers, communications equipment, and many other electronic and electrical devices. They have the same wirewound construction as the new miniature 3X resistor—differing only in size and wattage rating.

You'll find complete specification data on these larger miniature resistors in Ward Leonard's information-packed Catalog 15. (Complete data on the 3-watt unit will be found in Catalog 15, Supplement B.)



WARD LEONARD CATALOG 15. Sixty-five pages of data help you select the right resistor for any job.

And big ones, too!

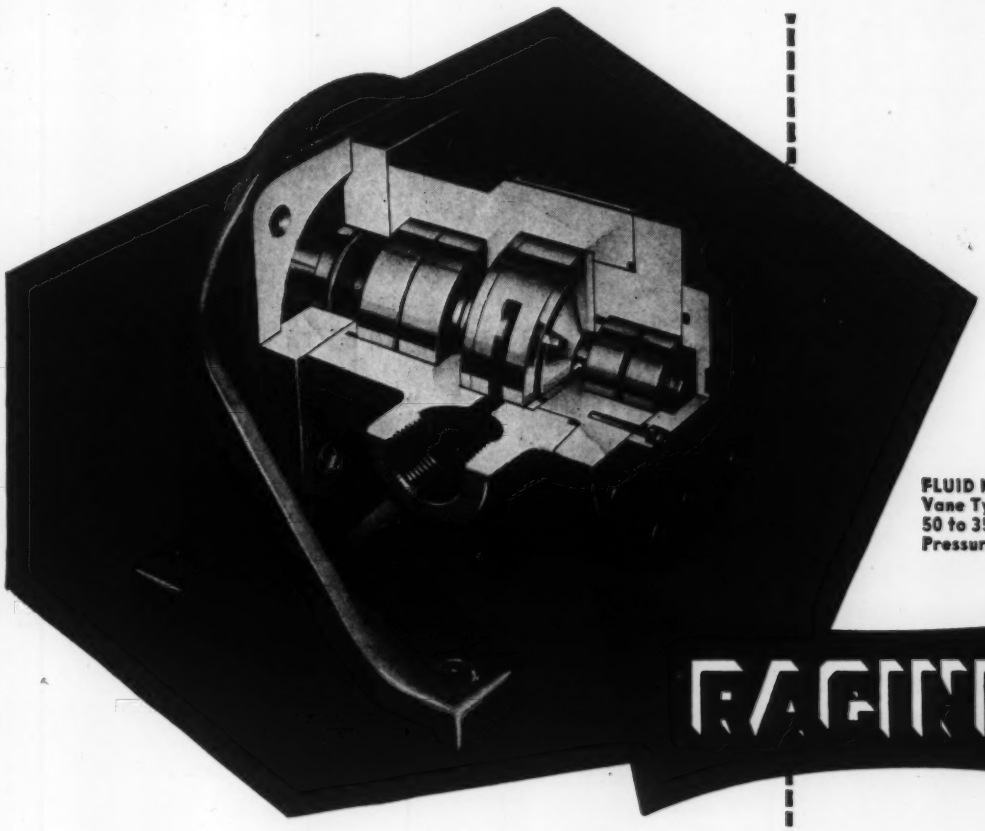
Ward Leonard Vitrohm resistors are available in stock sizes up to 200 watts. Similar resistors up to 550 watts are made on special order. You'll find these *power* resistors in a wide variety of mounting styles and types, tapped, untapped and regular or non-inductive wound, described in our big Catalog 15. Write for your copy today. 6.9

WARD LEONARD ELECTRIC COMPANY
58 SOUTH ST., MOUNT VERNON, N. Y.

Result-Engineered Controls Since 1892

RESISTORS • RHEOSTATS • RELAYS • CONTROLS • DIMMERS

Circle 548 on page 19



FLUID MOTOR
Vane Type
50 to 3500 rpm
Pressures to 1500 psi

RACINE®

A BETTER SOURCE OF ROTARY FORCE

Simple, compact and rugged in design, a RACINE Vane Type FLUID MOTOR transmits efficient hydraulic horsepower.

Note its simplicity and the minimum of moving parts, all of which are self-compensating for wear. Extra capacity bearings, heavy-duty shaft, tool steel vanes and alloy steel rotors, all contribute to efficient, dependable performance and maximum operating life.

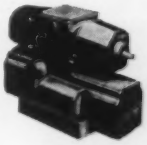
RACINE Vane Type FLUID MOTORS are available in several sizes with maximum output to 22 horsepower. Speeds from 50 to 3500 RPM — operating pressures to 1500 PSI.

Write today for full details. Let us show you why RACINE can give you "A Better Source of Rotary Force."

OTHER RACINE HYDRAULIC PRODUCTS

MODEL Q
Variable Volume
Vane Type
Hydraulic Pump

PRESSURE BOOSTER
Up to 5000 psi
Up to 7:1 pressure ratio



4-WAY VALVE
Twin Solenoid
Pilot Operated

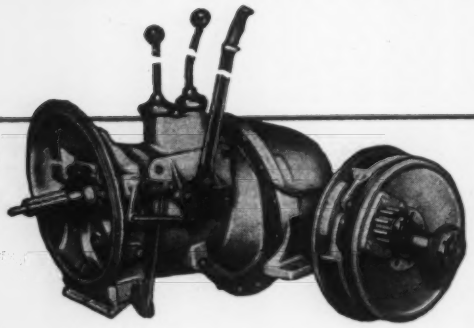
RESERVOIR
With Control Panel
Designed to your space
and circuit requirements

RACINE

NFPA NATIONAL FLUID POWER ASSOCIATION

RACINE HYDRAULICS & MACHINERY, INC.
2073 Albert Street
RACINE, WISCONSIN, U. S. A.

Circle 549 on page 19



Designed for RUGGEDNESS and DEPENDABILITY

For more than a quarter of a century Clark power transmission engineers have been thinking in terms of performance and outstanding dependability.

That's why, when *you* have a transmission, torque converter, drive unit or axle problem, you can find a solution by calling Clark. Seasoned, resourceful *Clark* engineers are always available to work with *your* engineers. Over the years dozens of manufacturers have found this "teaming-up" to be the quickest, easiest way to be certain of superior performance.

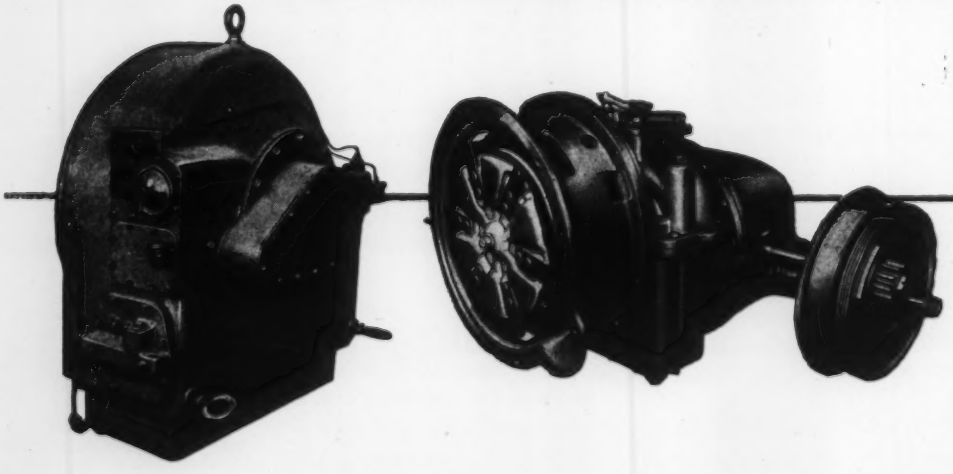
You'll find IT'S ALWAYS GOOD BUSINESS TO DO BUSINESS WITH CLARK.

CLARK® EQUIPMENT

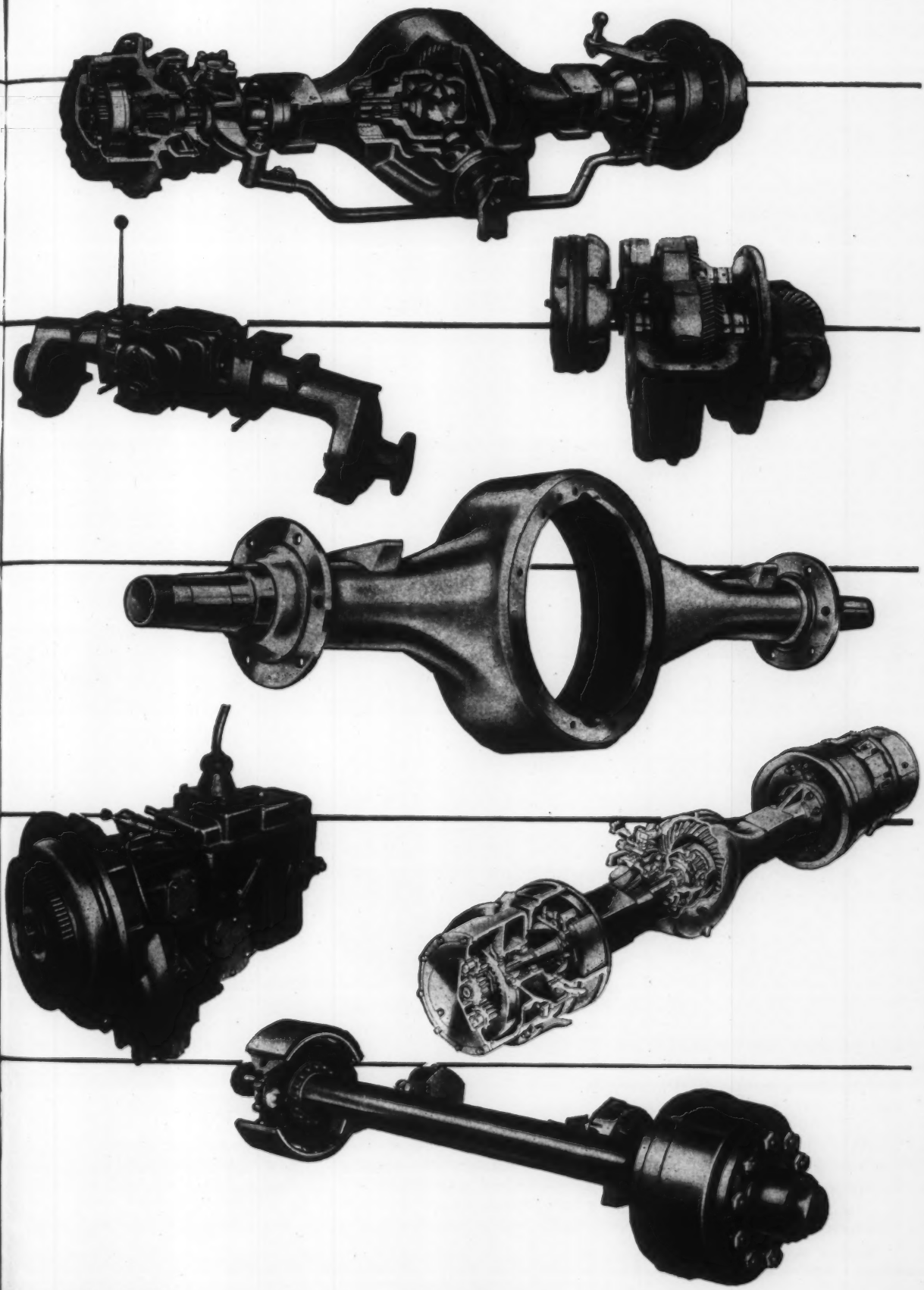
TRADEMARK OF THE CLARK EQUIPMENT COMPANY

CLARK EQUIPMENT COMPANY

Buchanan, Jackson, Benton Harbor, Battle Creek, Michigan

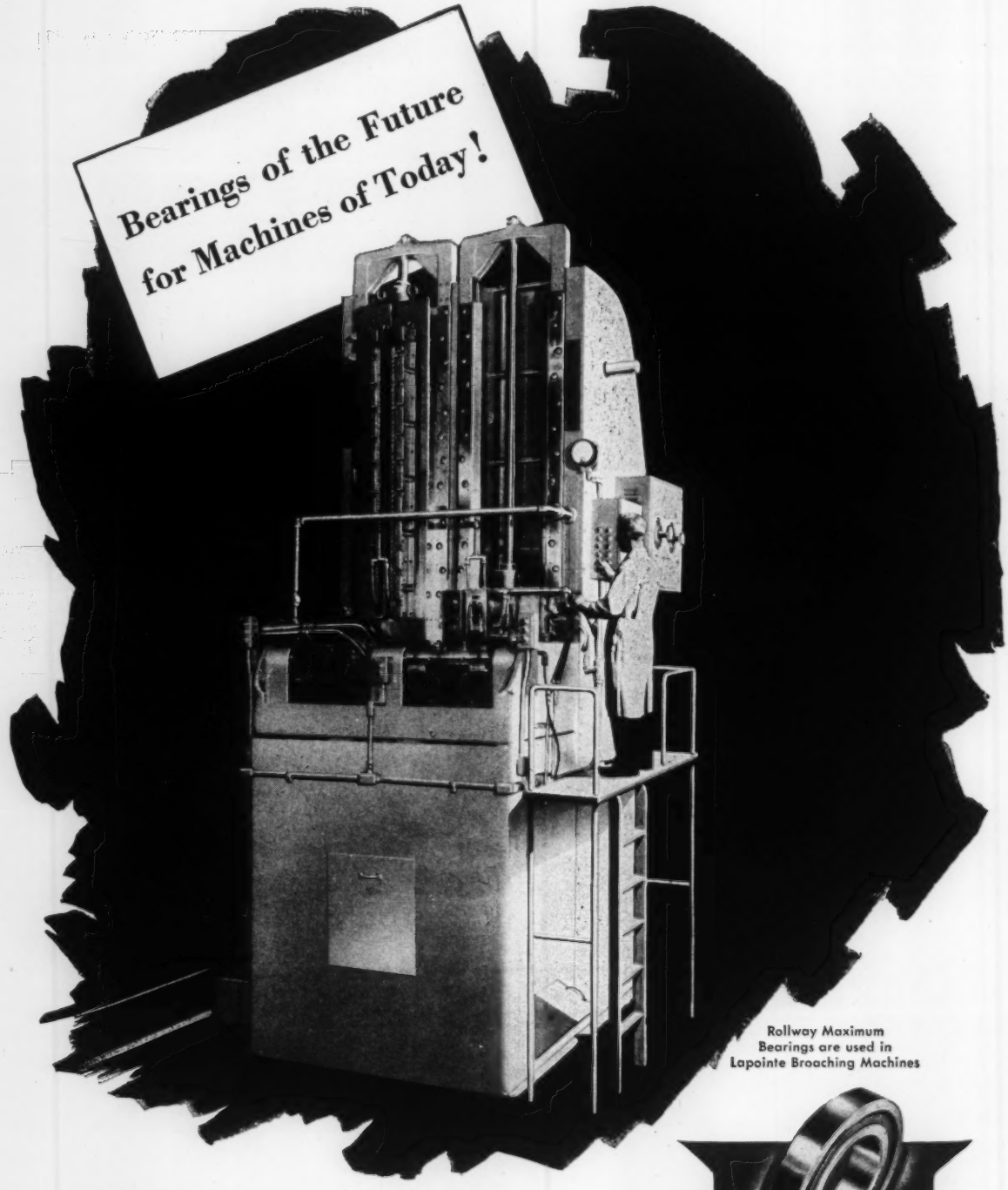


Write for this new 42 page book illustrating and describing the products and facilities of CLARK.



Circle 550 on page 19

Bearings of the Future for Machines of Today!



Rollway Maximum Bearings are used in Lapointe Broaching Machines

Rollway roller bearings regularly offer performance capabilities for more than the needs of today. They are continuously anticipating the operating requirements of years ahead.

Wherever bearing precision and load values are important in your plant or products — for original equipment or replacement service — call on Rollway *bearings of the future,* to give you the utmost performance in your machines of today. Rollway Bearing Company, Inc., 549 Seymour Street, Syracuse 4, N. Y. Manufacturers of a complete line of radial and thrust cylindrical roller bearings.

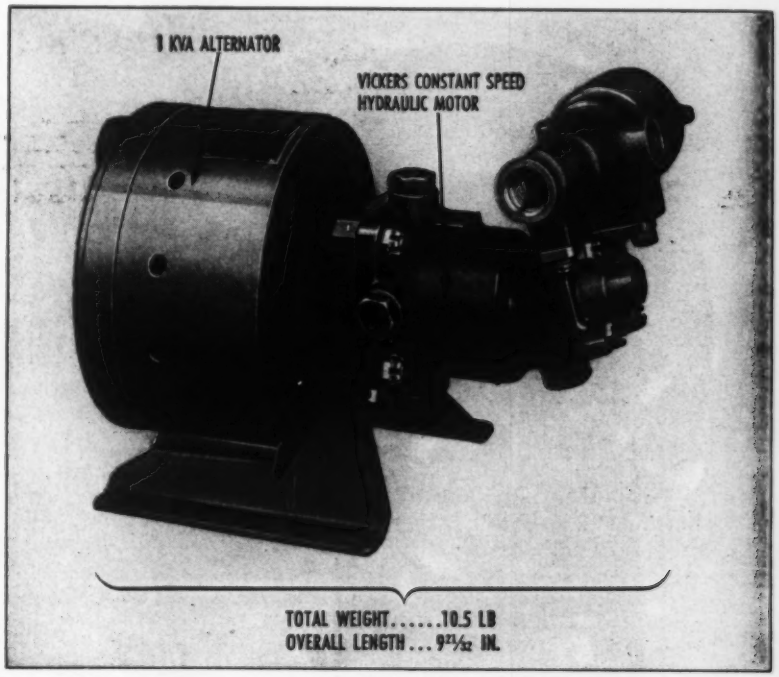
ROLLWAY
Maximum
ROLLER BEARINGS

ENGINEERING OFFICES: Syracuse • Boston • Chicago • Detroit • Toronto • Pittsburgh • Cleveland • Milwaukee • Seattle • Houston • Philadelphia • Los Angeles • San Francisco

New Vickers Airborne Electrical Power Package

. . . *Saves Weight and Space*

Utilizes the Hydraulic System for More Efficient Production of AC Power



This new isolated electrical power package provides closely regulated AC power with minimum weight and envelope while drawing its power from a hydraulic system. In new designs or when adding electronic equipment to aircraft designs in which the electrical system is already loaded to capacity, this versatile package provides the needed AC power from flow available in the hydraulic system. This generally is permissible without system change as the full flow is seldom demanded except for a few seconds under rare circumstances. Even in such cases, full flow can be guaranteed to these hydraulic functions through the use of a simple priority valve which starves the AC power package momentarily.

Less Weight and More Efficient

Important weight savings are achieved through the use of this package instead of an inverter which may also require an increase in the DC generator and line capacities. In one instance, the 10.5 lb 1 kva package replaced a 38 lb inverter for co-pilot instrumentation. An additional advantage is that the package has 62% overall efficiency while that of the inverter was 35-40%.

Extreme altitude operation is no problem as the Vickers isolated electrical power package contains no brushes or other altitude-sensitive components.

Features of AC Generator

The permanent magnet type AC generator has excellent life and reliability. It requires no bulky voltage regulator . . . is inherently smaller and lighter than conventional generators due to the elimination of the exciter and slip rings. It also has higher overall efficiency resulting from elimination of all excitation losses. Additional advantages are that the permanent magnet is unaffected by momentary short circuit, or separation of field and armature without keeper, or by temperature cycling. It is also not susceptible to aging or shock. This unit is 120/208 volt, three phase, wye connected with 400 cps at 8000 rpm. It is capable of continuous duty under environments of 0-55,000 feet altitude and ambient temperatures from −65 F to 250 F.

Hydraulic Motor Drive

The generator is directly driven by a Vickers Constant Speed Hydraulic Motor having fixed stroke and an integral flow control valve that maintains an 8000 rpm speed setting within ±2½% regardless of the load (as long as valve inlet pressure is greater than load requirement). For the unit shown above, maximum operating pressure is 3000 psi while rated output of 1 kva requires operating pressure of 2200 psi. Special configurations will maintain 400 cps frequency within ±0.1% regardless of load. This motor has a very high horsepower-weight ratio and its overall efficiency exceeds 92%. It is a time-proved design capable of many hundreds of hours of continuous service without attention.

Many Uses and Sizes

The applications for this isolated power source are numerous. For multi-engine aircraft, its use for co-pilot instruments provides dual reliability. This package has been used to supply controlled frequency AC power in emergencies when the only source of power in the airplane is a ram air turbine driven pump. The efficiency of this arrangement minimizes the size and weight of the ram air turbine necessary to provide emergency hydraulic and electric power. 7492

Now available in the sizes listed below, larger packages can also be supplied from existing components. Vickers is prepared to develop the package best suited to a specific need. For further information, write for bulletin A-5213 or get in touch with your nearest Vickers Aircraft Application Engineer.

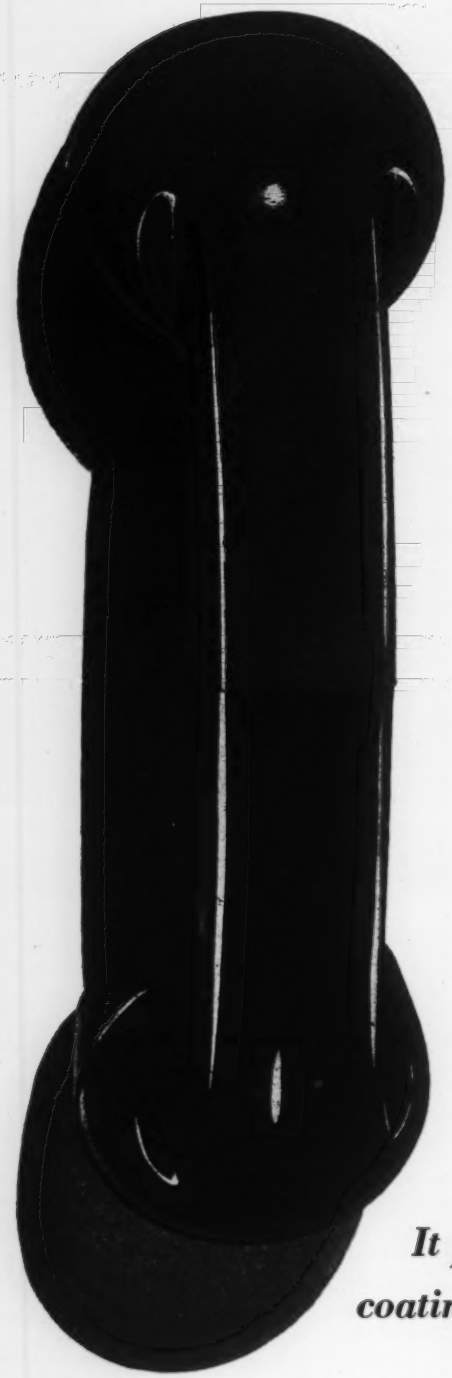
Vickers Airborne Electrical Power Packages

kva output	weight, pounds
0.5	7.0
1.0	10.5
1.5	12.5
2.0	15
2.5	17
3.0	19

Larger capacities with minimum weight are available.

VICKERS INCORPORATED
DIVISION OF SPERRY RAND CORPORATION
ADMINISTRATIVE and ENGINEERING CENTER
Department 1430 • Detroit 32, Michigan
Aircraft Application Engineering and Service Offices: El Segundo, California, 2160 E. Imperial Highway • Detroit 32, Michigan, 1400 Oakman Blvd. (Service Only) • Arlington, Texas, P. O. Box 213 • Washington 5, D.C., 624-7 Wyatt Bldg. Additional Service facilities at: Miami Springs, Florida, 641 De Soto Drive
TELEGRAMS: Vickers WUX Detroit • TELETYPE "ROY" 1149 CABLE: Videt
OVERSEAS REPRESENTATIVE: The Sperry Gyroscope Co., Ltd. Great West Road, Brentford, Middx., England

Engineers and Builders of Oil Hydraulic Equipment Since 1921



Here's a NEW way to

Have color...and keep costs down

You can do just that, with phenolic moldings economically and permanently colored (without the use of prime or multiple coats) by a new coating based on BAKELITE Brand Epoxy Resins.

Phenolics, of course, are recognized for their low cost, easy moldability, excellent dimensional stability and electrical insulating properties, resistance to heat, water and chemicals. But, until now, they had to be passed by when bright color was a requirement. Therefore, color meant higher costs with other materials.

Today, with the development of this new coating, manufacturers can have color in a single coat and still retain the production economies and quality advantages of phenolic moldings.

BAKELITE Epoxy Resins are well known for their adhesive properties. The new enamel not only adheres firmly to the glossiest phenolic surface, but equally well on steel, tin, brass, copper, aluminum, wood, and many other plastics. It has excellent heat, corrosion, chemical and abrasional resistance. A wide range of colors is available, with finishes from dead flat to high gloss. Curing is by air drying, force drying, or baking. Air-dry pieces can be handled in about two hours . . . and the possibility of curing with low or no heat opens up the field of precision parts to color. A further advantage in production is that color is switched at the spray booth, not at the molding machine. Changeover time is eliminated. Inventory of colored raw materials is cut.

Investigate these new coatings. They can give you new ideas on how to design for color . . . as well as economy. Write Dept. VJ-103.

It pays to specify coatings based on...

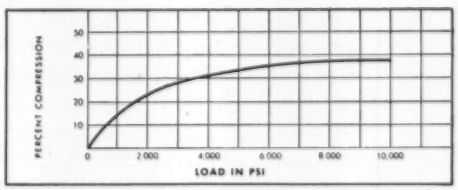
BAKELITE
BRAND
EPOXY RESINS

Rexton Finishes, Inc., Irvington, N. J., developed the coatings described.

BAKELITE COMPANY, *A Division of Union Carbide and Carbon Corporation* UCC 30 East 42nd Street, New York 17, N. Y.

The term BAKELITE and the Trefoil Symbol are registered trade-marks of UCC.

New fiber gasket takes heavy loads with minimum bolt-torque loss

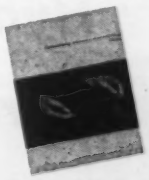


COMPRESSIBILITY. N-820, less compressible than other Accopac materials, is recommended for heavy-duty applications where flange pressures will be 2000 psi or more and temperatures do not exceed 250° F.

With Armstrong N-820 Accopac®, you can handle sealing jobs at high flange pressures even where temperatures at the gasket line go as high as 250° F.—conditions under which ordinary plant-fiber gaskets would permit serious loss of bolt-torque.

Field experience with N-820 Accopac shows that it has a maximum torque loss of 10-15%. This unusual performance often eliminates the need for re-torquing bolts in order to maintain the desired bolt pressure.

N-820 is made by a patented Armstrong process in which cellulose fibers are beater-saturated with a non-volatile latex binder. The result is a dense, crush-resistant material which has excellent torque-retention characteristics.

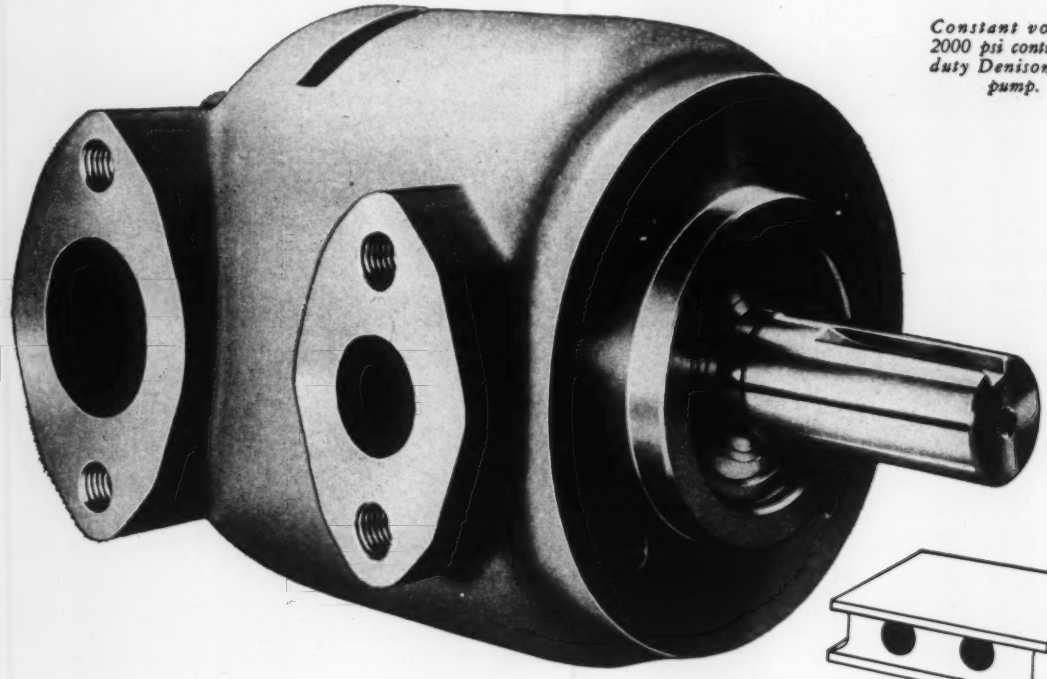


For more information on N-820 Accopac, write Armstrong Cork Company, 7011 Dean Street, Lancaster, Pa.

Armstrong ACCOPAC

. . . used wherever performance counts

Circle 554 on page 19



Constant volume 2000 psi continuous duty Denison vane pump.

Hydraulically balanced vane utilizes internal oil pressure to maintain constant pressure of sealing edges against cam ring.

2000 PSI VANE PUMPS

Proper Application

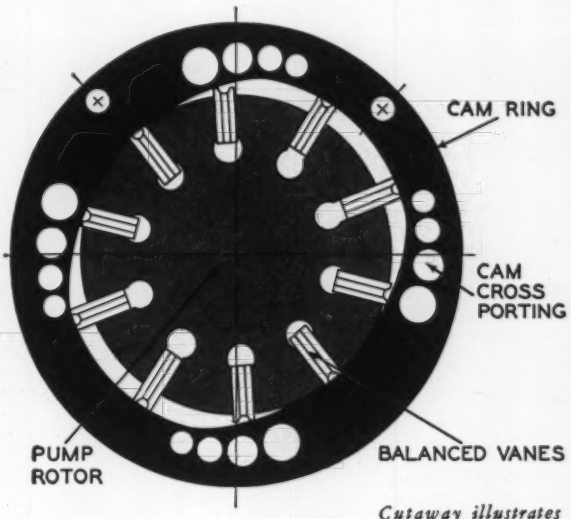
Hydraulic Performance

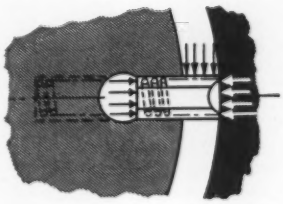
Operating Characteristics

By **Ellis H. Born**
Chief Application Engineer
Denison Engineering Division
American Brake Shoe Co.
Columbus, Ohio

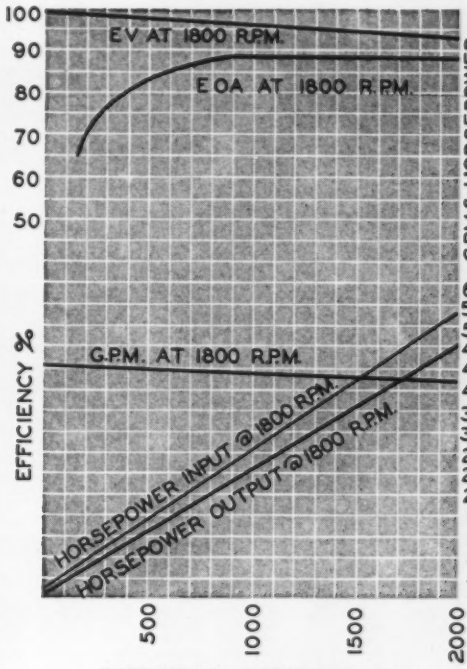
INEFFICIENCIES introduced by line loss are reduced 50% by increasing the pressure from 1000 to 2000 psi.

In designing hydraulic circuits, it is normal to limit line velocities to a maximum of from 15 to 20 feet per second, permitting the use of the smallest practical lines, valves and fittings. The pressure drop in transmitting the fluid medium is thus dependent on flow velocity, number of valves and fittings, and line length. If, for example, the pressure drop of a given system is 50 psi, this would represent a loss in transmission of 5% for a 1000 psi system and a loss of





Cutaway illustrates pump rotor and cam ring assembly. (Below) Pressure balancing relieves hydraulic bearing loads between vanes and cam ring.



Performance Curve of 2000 psi vane type pump illustrates high volumetric efficiency attained with double seal, balanced vane construction.

2.5% for a 2000 psi system. The power lost in transmission is thus reduced 50% by using 2000 psi components.

In sizing components for the transmission of a given horsepower, an interesting comparison of component size, weight and costs can be made. For example, if a job requires the transmission of 16 horsepower, a flow of 16 GPM at 2000 psi working pressure, or 32 GPM at 1000 psi, would be required. Thirty-two GPM would require 1¼" valves, but 16 GPM only ¾" valves. The use of the higher pressure results in a great advantage in that the hydraulic system can be set up with components of lower weight, lower cost per horsepower and smaller, more easily installed pumps, motors and valves.

Additional gains in hydraulic efficiencies are realized by the fully balanced design, not only on the rotor, but on the vanes themselves. Four years of field experience shows that high volumetric efficiencies are maintained over longer periods of service. Wear on cam rings is reduced over conventional designs where the vane is held against the cam ring by hydraulic pressure.

The balanced vane is achieved by a construction allowing the vane to be open at both ends to pressure on the pressure stroke, and to suction on the suction stroke.

Specifications and application data on this vane pump, which also operates as a hydraulic motor, are available by writing.

DENISON ENGINEERING DIVISION
American Brake Shoe Company
1240 Dublin Road, Columbus 16, Ohio

REQUEST FOR APPLICATION DATA

fill out and mail to
DENISON ENGINEERING DIVISION
American Brake Shoe Co.
1240 Dublin Road
Columbus 16, Ohio

Please send specific data on proper application of vane pumps for my needs. Problem is _____

_____

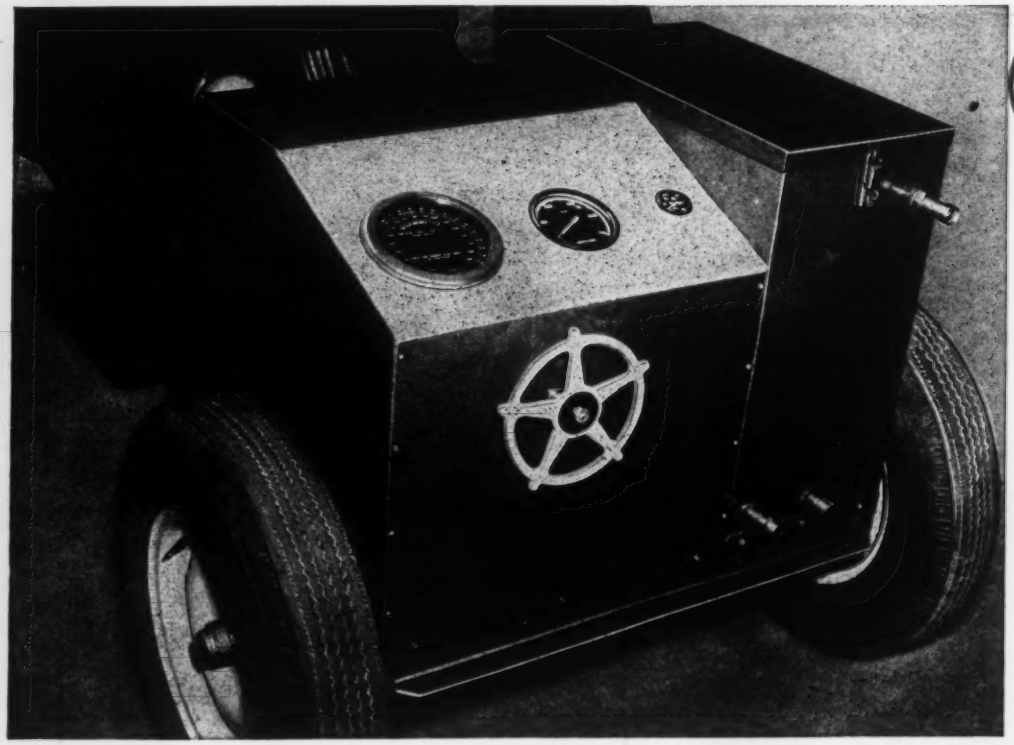
Name of Company _____

City _____ *State* _____

Name _____

Position _____

Circle 555 on page 19



WHAT'S **NEW** AT BLOOD BROTHERS

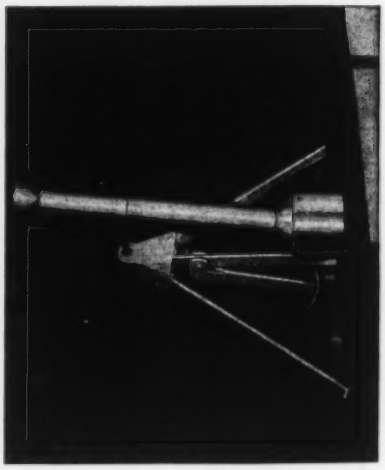
BLOOD BROTHERS P.T.O. Drive Lines

Selected by M&W GEAR CO., Inc. for

Exciting NEW TRACTOR-TESTING DYNAMOMETER

Tractor repairmen and dealers are enthusiastic about this new test unit because it meets a real need in the farm tractor field. The only machine of its kind on the market, M&W's new dynamometer brings actual field operating conditions into the shop. Mechanics can test the pull power of farm tractors and accurately adjust ignition, carburetion and engine speed under full load for peak performance and economy.

Here's another example of the preference shown by farm implement manufacturers for Blood Brothers Drive Lines. They're selected for almost all new developments and improvements by the progressive Implement Industry because of their field-proven dependability and superiority.



Blood Brothers Safety-Shield Drive Line handles torque loads easily—and protects mechanics working in close quarters around tractor and dynamometer in garage or implement repair shop.

FOR FARM IMPLEMENTS, MORE BLOOD BROTHERS UNIVERSAL JOINTS ARE USED THAN ALL OTHER MAKES COMBINED.

TRUCK POWER AROUND CORNERS

BLOOD BROTHERS MACHINE DIVISION

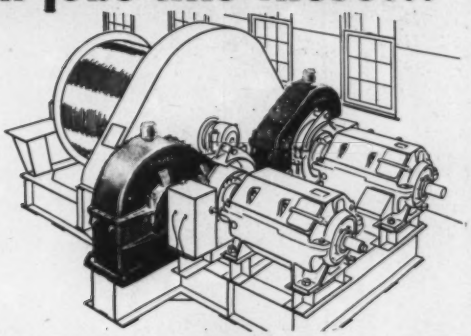
ROCKWELL SPRING AND AXLE COMPANY

ALLEGAN, MICHIGAN

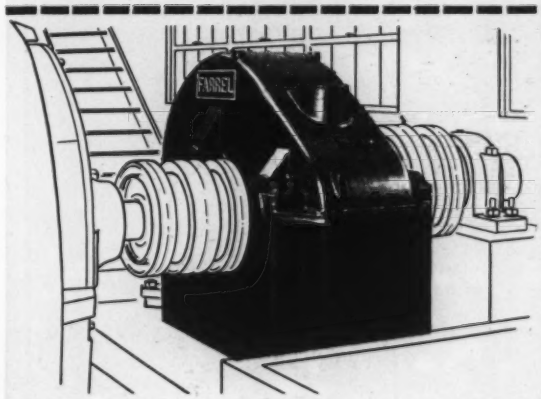
UNIVERSAL JOINTS AND DRIVE LINE ASSEMBLIES

Circle 556 on page 19

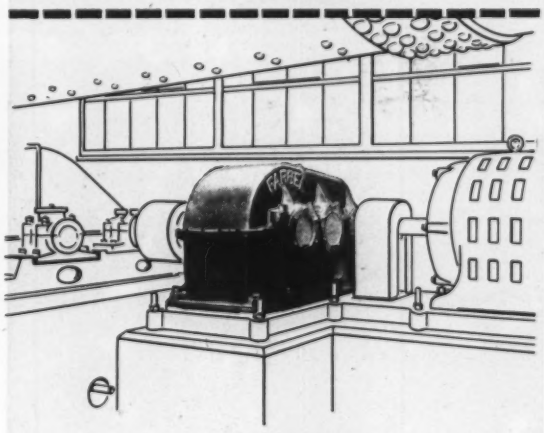
on jobs like these...



. . . A SKIP HOIST



. . . A ROLLING MILL



. . . A ROTARY KILN

Farrel® speed reducers pay off with benefits like these

EXTRA LOAD-CARRYING CAPACITY

The gears in a Farrel speed reducer are continuous tooth herringbone. Instead of a center groove they have a *backbone* where the helices meet. This *backbone* puts the full width of each gear to work transmitting power, providing extra strength and greater load and shock capacity in smaller space . . . perfect for speed reduction jobs.

SUSTAINED EFFICIENCY

When you specify Farrel, you're assured of sustained operating efficiency throughout a long service life, thanks to sound engineering, accuracy of manufacture and use of highest grade materials. Gears are precision-generated; a husky housing maintains operating smoothness of working parts; bearings are antifriction throughout; lubrication is continuous splash for the gears.

BROAD SELECTIVITY

Name the job . . . Farrel has the speed reducer. Both heavy-duty and light-type units are available in a broad range of sizes, and in a series of standard ratios as follows: *Single reduction* — from 1½:1 to 10:1; *double reduction* — from 10:1 to 70:1; *triple reduction* — from 83.9:1 to 323:1. Special designs are obtainable.

These benefits, together with many others, are the result of experience gained in thirty-five years of speed reducer manufacturing. They add up to give you year-round, trouble-free service. Write for free booklet which details the full line of Farrel speed reducers. Ask for Bulletin 450.

FARREL-BIRMINGHAM COMPANY, INC.
ANSONIA, CONNECTICUT

Plants: Ansonia and Derby, Conn., Buffalo and Rochester, N. Y. *Sales Offices:* Ansonia, Buffalo, Boston, Akron, Ann Arbor (Mich.), Chicago, Minneapolis, Fayetteville (N. C.), Los Angeles, Salt Lake City, Tulsa, Houston

Farrel-Birmingham®

FB-1103

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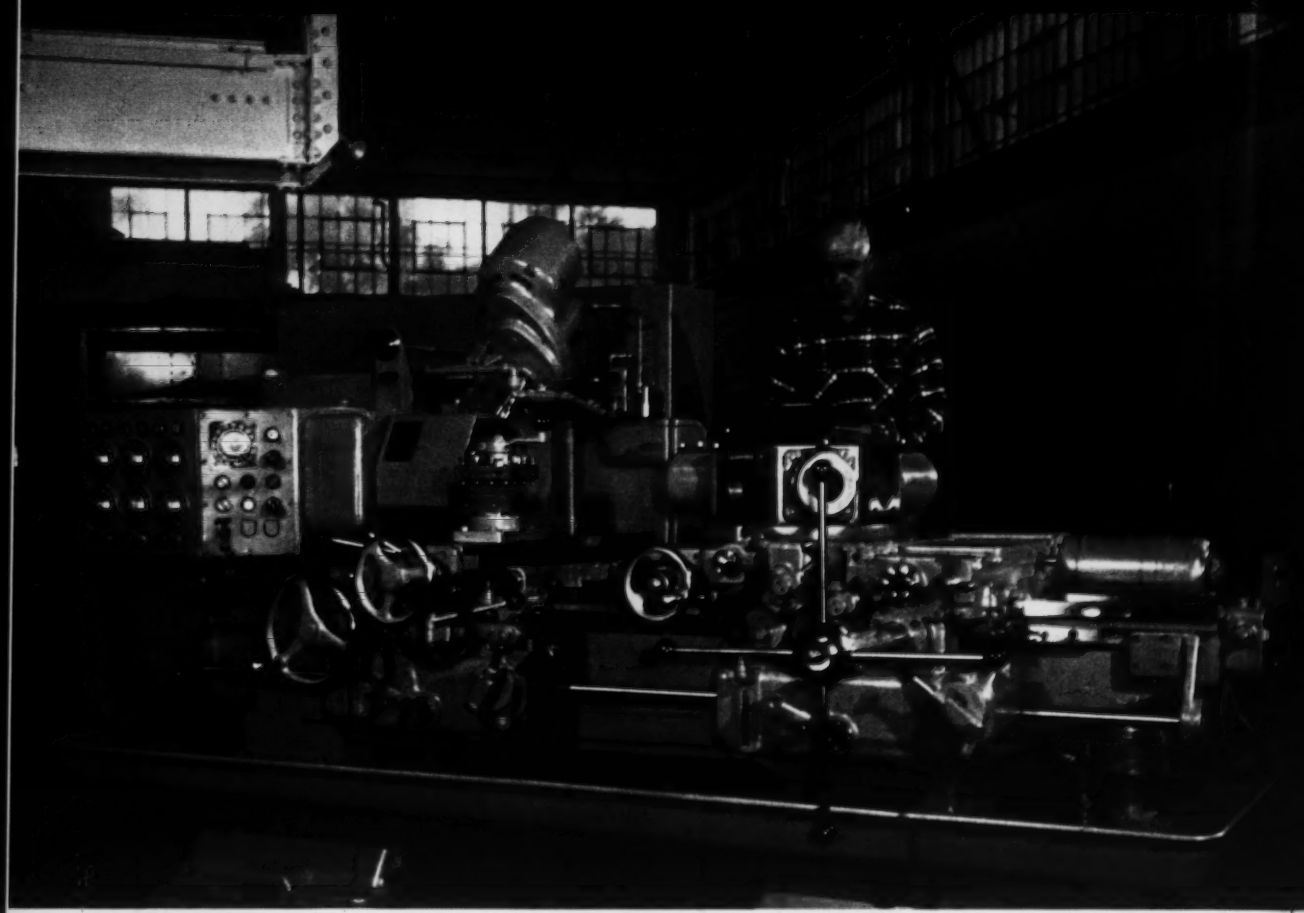
Circle 558 on page 19→

G-E general purpose control



Hydra-clutch Headstock with G-E controls automatically changes pre-selected spindle speeds for each hexagon turret position.

G-E PANEL PROVIDES AUTOMATIC SPEED SELECTION FOR EACH OF 6 TURRET FACES

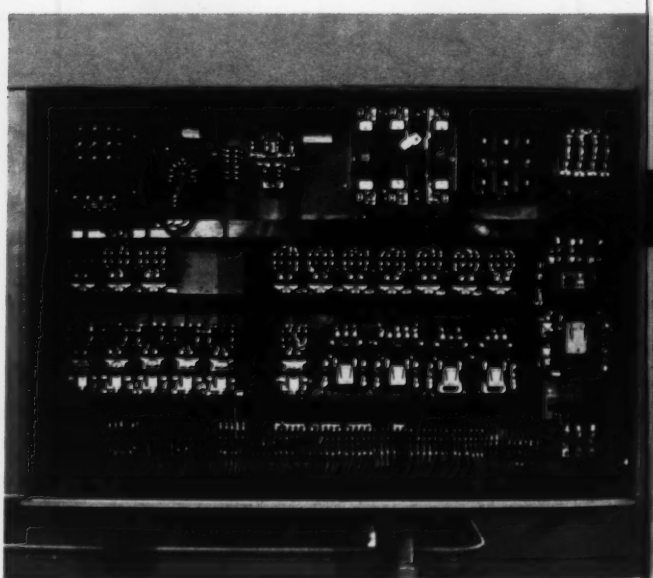
The new Hydra-clutch Headstock manufactured by the Jones & Lamson Machine Company is controlled by a General Electric factory-built Pan-A-trol packaged control panel. This machine is designed to reduce machine handling time and operator fatigue.

Equipped with a power indexed hexagon turret, the Headstock features pre-selected spindle speeds which are automatically changed for each of the six turret faces. Speed selection and changes, and power indexing are controlled by G-E oil-tight push buttons and selector switches, along with indicating lights, in the operator's station.

The factory-built panel is constructed to JIC standards, and contains standard high-quality G-E starters, machine tool relays, pneumatic time-delay relay, and other devices. The machine tool relays control the power feed and indexing of the turret head.

Latched-in forms of the machine tool relay control solenoid valves. Spindle speed changes are accomplished by these valves engaging or disengaging hydraulically operated multiple-disc clutches.

This Pan-A-trol packaged control panel was shipped from our factory completely wired. Only connections from the machine to the panel terminal board had to be made.



PAN-A-TROL PANEL was factory-built to JIC standards. Panel provides: motor starting; motor reversing; motor overload protection; over-current protection; and a disconnecting means.

GENERAL ELECTRIC'S NEW

Machine Tool and Time-Delay Relays Control New 32-speed Headstock

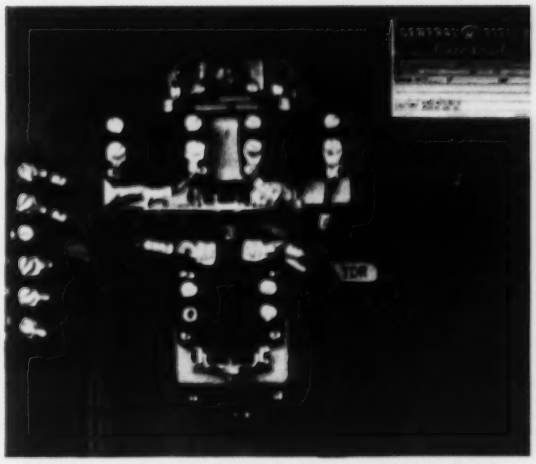
General Electric's new machine tool relays and pneumatic time-delay relay, installed in a G-E factory-built Pan-A-trol* packaged control panel, provide precise control for this 32-speed Hydra-clutch Headstock, manufactured by Jones & Lamson Machine Company of Springfield, Vermont.

MACHINE TOOL RELAYS offer a high degree of dependability on automatic machinery such as this Headstock. The Strongbox coil in the machine tool relay is molded in a polyester resin to seal out moisture and oil. Permanently attached contact springs assure proper tip pressure. Also, contacts change from normally open to normally closed without extra parts.

PNEUMATIC TIME-DELAY RELAY provides high repetitive accuracy with negligible effect from humidity or atmospheric pressure changes. It is adjustable from 0.2 to 180 seconds. A rigid die-cast aluminum base prevents misalignment which might affect relay accuracy.

FOR MORE INFORMATION, contact your nearest General Electric Apparatus Sales Office, or write Advertising and Sales Promotion, Section 731-4, General Electric Company, Bloomington, Illinois.

* Trade-mark of General Electric Co.

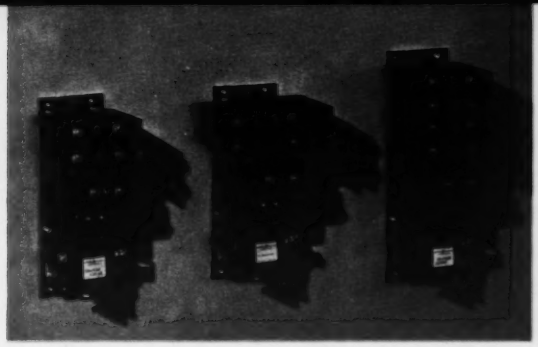


PNEUMATIC TIME-DELAY RELAY prevents operation of power wrench on Headstock before it stops spinning.

GENERAL ELECTRIC

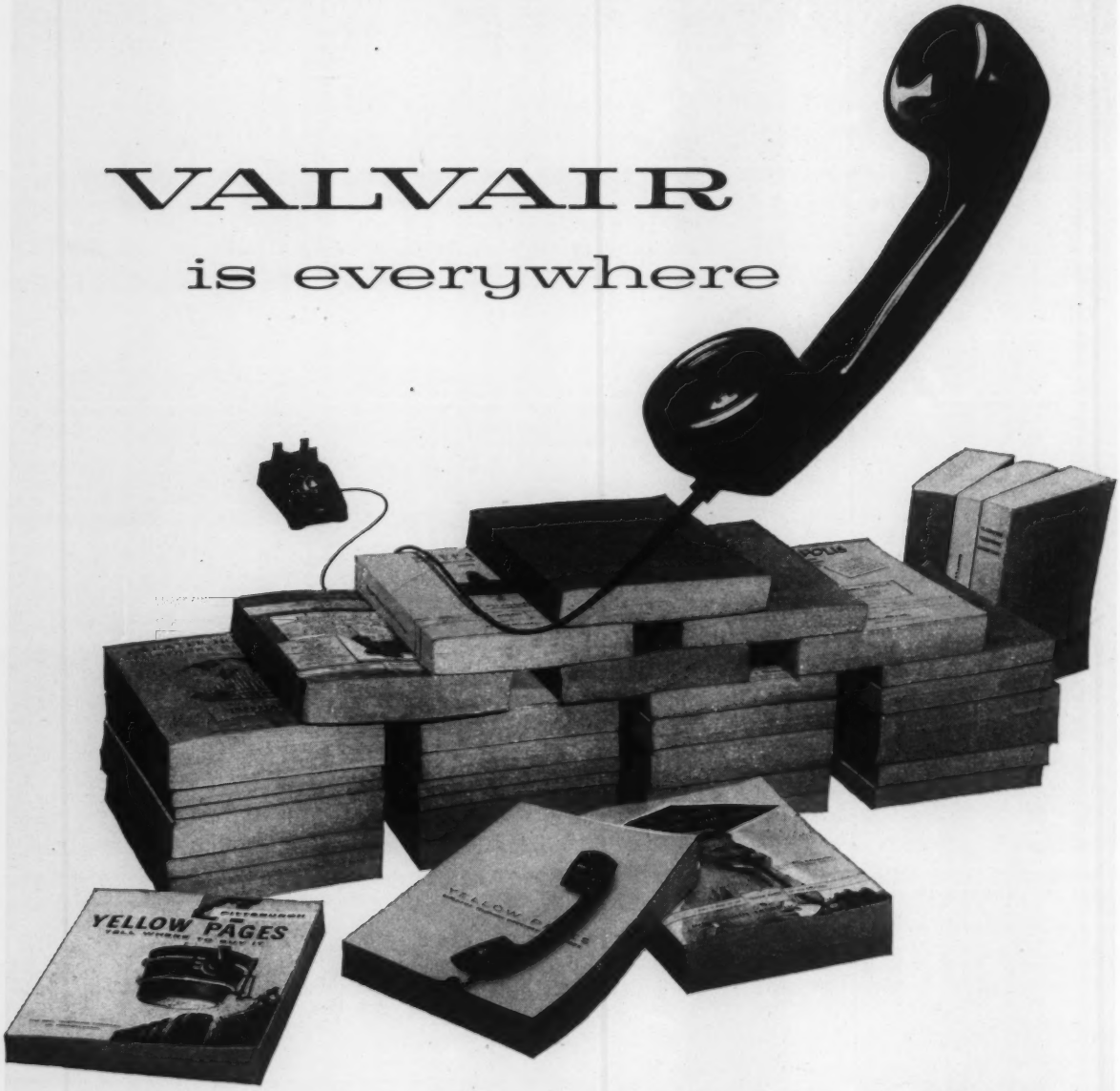
GENERAL ELECTRIC'S MACHINE TOOL RELAY FAMILY

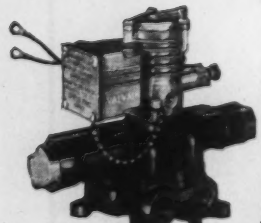
MACHINE TOOL RELAYS have front-connected terminals, can be wired from four directions for easier installation. Also, three keyhole slots simplify mounting the relay.



LATCHED-IN FORMS have a standard machine tool relay plus a latching mechanism, which mechanically holds the contacts closed to maintain the continuity of sequencing.

VALVAIR
is everywhere





Compare... and you'll buy

Valvair

Write for free copy of new Bulletin SK356

Valves — by Valvair — are everywhere . . . on the best production and automated equipment . . . in mills, factories, foundries and assembly plants.

That's because they deliver *performance.* Users report Speed Kings are still working satisfactorily after 25 million cycles. And they're *guaranteed against coil burnout* for the life of the valve. What's more, with Valvair valves you pay for only the features you want for your specific application.

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MACHINE DESIGN
November 29, 1956

The Hard Core

WHEN the civil engineers divorced themselves from the military and were in turn divorced by the mechanicals and electricals, the primary concern of the two latter groups was power. The civils concentrated on structures while the mechanicals and electricals devoted themselves to machines for the production and utilization of power.

Thus the broad activity known as machine design was born. Early machines were designed primarily to extend man's muscle power—mechanization. With drives providing the muscles, controls provided the supervision or direction.

This issue of MACHINE DESIGN is the twentieth in an annual series devoted to drives and controls, which continue to be the hard core about which all other aspects of the design of a machine revolve. As the diversity of drive and control methods and equipment has grown, these issues have served an important purpose in focusing attention, in one place at one time, on all phases including mechanical, electrical, electronic and fluid power.

Whatever the end use of machines—for transportation, for performing household tasks, for generating power, to cut metal or to drill holes in teeth—it is their drive and control elements that give them the kinship which cements and defines the scope of what we call machine design.

Colin Carmichael

EDITOR

ENGINEERING ORGANIZATION

Topsy's belief that she wasn't born but just growed aptly characterizes many engineering departments. Management concern is justified when engineers appear to be an aimless aggregate rather than a well co-ordinated team.

Many weaknesses in the engineering program can be traced to organizational defects. Organization isn't a panacea for every problem in the engineering department, but a sound organization structure will carry the engineering manager over many rough spots that would spell disaster in an otherwise weak organization.

This article presents the four steps essential in the building of an effective engineering organization.

SOUND organization structures provide a framework for effective engineering activities. Inadequate organizations magnify operating weaknesses.

If engineering management knows what it wants to do and sets up the proper organization, staffs it adequately, and manages it soundly, any desired objective can be achieved within practical limits. Success has been built on this principle. When the inherent wisdom of this principle has been ignored, important engineering undertakings have failed.

The starting point in building a successful engineering operation is basic organization. Yet this vitally important first step is the last one taken by some engineering administrators.

The organization structure establishes the framework within which operations take place. Once the broad functions to be performed have been determined, the organization structure determines interrelationships that should exist between these functions for maximum working effectiveness. In addition, formal organization steps put everyone concerned on notice that specific relationships do exist and are to be observed in the interests of harmony.

Organization is a continuing process. Not only must it precede operations but organization itself must develop along with engineering activities. Today's engineering operations can't be carried out effectively with yesterday's organization. Technology strides forward rapidly. Technical organizations must keep pace by means of a continual process of organizational development. An organization begins to be outmoded by progress the moment the initial organization structure is completed. Organization development must be recognized as a continuing management function.

As rapidly as technological innovations appear, as promptly as engineering work points toward new horizons, the engineering organization should be revamped to fit new requirements. Acceptance of the need for these new requirements has been one of the apparent secrets of the success of expanding engineering departments in growth corporations.

The Administrator's Key Role

Sound management is based on practices that have proved successful. Fortunately engineers can test ideas in the experimental laboratory under carefully controlled conditions and on a scale commensurate with the risks and costs involved. On the unfortunate side, management ideas can rarely, if ever, be proved by a laboratory-scale experiment. Operations themselves must provide the proving ground.

Consequently, management knowledge must be gained largely from a study of the experiences of others. Because opportunities are limited for testing out new concepts and ideas, it is even more imperative that these practices receive the careful attention and consideration of management men lest new developments go unrecognized.

Final decisions on engineering management matters must be made by the engineering administrator. No one can execute the manager's function but the manager himself. His training background and experience represent years of preparation for

for Profitable Performance

By Philip Marvin
American Managament Association
New York

decisions that he alone must make.

Execution of this responsibility calls for knowledge and facility in applying organizational concepts within the engineering operations. To a degree, outside assistance may be retained but the final responsibility for action rests with the engineering administrator, not an outsider. There are very few individuals who are competent to help the engineering administrator. Demands on their time are heavy; their availability when most needed is limited.

Engineering administrators should be particularly critical in selecting outside consultants. They should inquire into the actual "on the job" experience of the consultant in the particular field in which the consultant professes competence. Such references should be tracked down and checked.

Anyone can call himself a consultant; few qualify in competence. Qualified consultants are willing to provide references. References should be of two types—those who can testify as to the consultant's practical experience on the job and those who can testify as to the consultant's ability to act effectively in an advisory capacity.

The only type of individual whose consultation is worth much to the engineering administrator is a man who, prior to undertaking to offer a consulting service, has had from 10 to 20 years of experience in industry in a responsible operating position in the area of his subsequent professional specialty. The number of such individuals available in relationship to the number who offer consulting services is small.

It can be readily appreciated that the engineering manager's responsibility is not one which can be readily transferred even in part. To act effectively, the engineer administrator should have a first-hand appreciation of organizational fundamentals.

Engineering Assignments Determine the Most Suitable Type of Organization

There isn't any best type of engineering organization. Every engineering group is faced with a different assignment. Individual assignments determine the type of organization needed for optimum output.

Objective organization planning is based on the jobs the engineering group must tackle. A model organization should be built around actual requirements. The existing organization should then be compared with this model before any reorganization activity is programmed.

Engineering managers experience most of their trouble in developing the model organization around basic work requirements. Once this step is completed, once they have their model, it appears to be relatively easy for them to reshape the existing structure to the new pattern. The difficulty experienced in developing a model organization is usually traceable to the lack of a plan of attack. Armed with a clearly defined course of action, engineering administrators generally experience little difficulty in attacking organizational problems. Several clearly defined steps are recognizable as essential in organization building.

Step 1: Define Functions To Be Performed

Engineering objectives vary from company to company. Overall objectives most commonly fall into eight categories.

1. Development of radically new products, processes and manufacturing equipment.
2. Development of lower-cost products, processes and manufacturing equipment.
3. Development of new and improved functions in products, processes and manufacturing equipment.
4. Establishment of standards.
5. Control of quality.
6. Technical service to divisions and customers.
7. Design and maintenance of production equipment.
8. Technical counsel to corporation, customers and special-interest groups.

In any engineering department, these broad objectives can be narrowed down into specific and immediate demands. Analysis of these specific demands on the engineering department reveals to the engineering manager the types of distinct

activities that must take place within the department.

These functions are either of a technical nature or of an administrative character. These distinct activities are the building blocks of the organization. Failure to give recognition to each of these vitally important functions in developing an organization can result in seriously limiting the effectiveness of the organizational programming.

Step 2: Establish Functional Groupings

Technical considerations determine the grouping of functions within the engineering department to a large degree. The result often presents an unwieldy structure from an administrative position. Not more than five individuals should report to the top engineering administrator if he is to have time to execute the responsibilities of his office. This policy must be carried down into lower echelons. As managerial responsibilities give way to purely supervisory duties, the number of reporting individuals can be increased.

Experience has proved that engineering administrators are effectively served when engineering activities report to them through a technical director and an administrative director. There is considerable merit in this structure. Hard-to-find technical people are spared many time-consuming administrative duties. In addition, administrative duties are grouped with resulting uniformity of policies and procedures.

Whatever the decision with respect to reporting functions, in arranging groupings it is important to minimize the number of individuals reporting to those charged with managerial responsibilities. The allowable maximum appears to be three line executives reporting to the chief engineering executive. As many as five line managers may be acceptable in reporting relationships at lower echelons.

Step 3: Develop Line Relationships

The chief engineering executive occupies the top position in the line of authority for engineering activities. Centralization of authority in the hands of the chief executive provides for quick, decisive action and flexibility. The premise is, of course, that he understands how to use his line executives in a way that permits them to operate in an efficient manner.

Engineers in line positions should have complete authority to make all decisions on matters for which they are held responsible. Engineers who are placed in management positions without adequate authority to act lack one of the most important tools of management.

Engineers in line positions should be accountable to a single superior and in turn should establish simple and direct lines of authority and accountability within their own areas of responsibility.

Proper relationships between responsibility, authority and accountability must be preserved if line organizations in the engineering department are to function smoothly. Each engineer in a line management position is accountable only to the executive directly above him and he should be vested with complete authority associated with his area of responsibilities.

Step 4: Utilize Staff Services

Successful engineering administrators make use of staff services to multiply their effectiveness. Executives can't personally investigate every matter of importance related to their decision-making responsibilities. They can't keep informed on all subjects in rapidly advancing technological areas. No one has succeeded in being an expert in every field which the engineering manager must cope with in administrative work. Engineers who have tried have become so hopelessly enmeshed in detail that they have failed in their administrative assignment.

In these words from Plato's *Republic,* Socrates stresses the advantages of specialization, "Things will be better done when each man is free from the distraction of other occupations to do the job for which he is best fitted and to do it when it should be done." Astute engineering managers heed the wisdom of these words and capitalize on staff activities in distributing the details of their work load.

Staff functions relieve executive pressure in two principal ways:

1. Portions of the executive's work load are absorbed.
2. Requirements for specialized knowledge on the part of the executive are transferred to a staff advisory function.

Staff members report directly to the executive. They are properly responsible for the specific investigatory, informational and counseling services they provide to this executive. They are not responsible for any of the activities of the line executives in the next lower echelon, nor should they have any authority over these executives.

For example, a chief engineer may have three line executives who are responsible respectively for design, mechanical model development and pilot production facilities. In addition to the three line executives who are responsible for these three departments, the chief engineer may have in his office a staff activity which is centered around operations analysis and which periodically calls to the attention of the chief executive specific problem areas which are developing within the engineering departments. Recommended courses of action to alleviate the problem usually accompany such reports. The chief engineer may have another staff group reporting competitors' activ-

ities to him. Still other staff functions may appear.

All staff functions fall under one of these labels —investigatory function, informational function or counseling function. Each represents a segment of the engineering manager's responsibility which has been detached and established as a specialized staff function in order to multiply the engineering manager's effectiveness.

Tests of Good Organization

Patterns for engineering organizations can't be picked out of the files. Engineering organizations must be tailored to the corporation's needs.

The ground rules for developing sound engineering organizations aren't as well developed as engineering managers might wish. Technological advances have taken place at such a rapid rate that a backlog of management experience has been difficult to accumulate. Organizations which have been developed according to known management fundamentals can be subjected to certain tests which will further prove out their inherent soundness. Eight tests have proven useful in this respect. Engineering organizations that pass all eight tests are in a healthy condition from a structural viewpoint.

1. Have areas of individual supervisory responsibility been clearly defined?
2. Has full authority been delegated to the engineer responsible for each activity?
3. Are engineering executives accountable to a single superior?
4. Is stability a characteristic of the organization?
5. Are individual functions balanced for harmonious working relationships?
6. Is the organization flexible?
7. Can the organization grow?
8. Is organization reduced to its simplest possible form?

Organizational simplicity is of such importance to overall soundness that it merits special consideration. Once an organization is completed, it should be subjected to one final test by applying this question to each position, "Would the corporation suffer either the loss of immediate profits or long-range growth opportunities if this position were abolished?"

Profits And Prospects

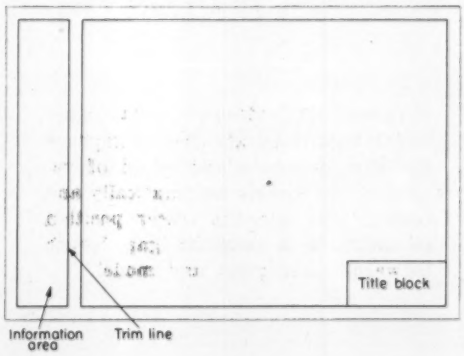
In today's competitive technological environment, the engineering organization's soundness determines to a large degree the corporation's future growth and progress. Farsighted management men are actively concentrating their attention on this phase of corporate activities.

The meagerness of the ground rules for organization development doesn't lessen in any way the vital importance of the soundness of the engineering organization in the overall corporate framework. Some executives can be expected to be luckier than others in developing their engineering organizations. But for most the results will be directly related to the soundness of the approach to organizational development and the willingness to accept this task as a continuing, day in and day out, executive assignment and responsibility. Happily, as a reward for a job well done, this assignment promises an increased productive and profitable output from the corporation's investment in engineering activities.

Tips and Techniques

Deleting Tracing Information

Often a tracing will incorporate much information that for one reason or another should be deleted from reproduced prints sent out to customers or other concerned parties. Inclusion of a separate block at one side of the tracing in which such information can be placed permits this portion of the print to be easily trimmed off with a neat print remaining.—ROGER ISETTS, *Kenosha, Wis.*



Lettering System

Fast, easy and neat lettering can be done by using a T-square or other straightedge as a guide for the bottom of the lettering only. The straightedge is held in the desired position and used as a stop for the bottoms of all letters as well as a guide for bottom strokes of letters such as *B* and *S*. Although tops of the letters may be slightly uneven, the general effect is still quite neat. Flattened bottoms of letters such as *S* and *O* give the lettering a distinctive character.—HAROLD BELOFSKY, *Bronx, N. Y.*

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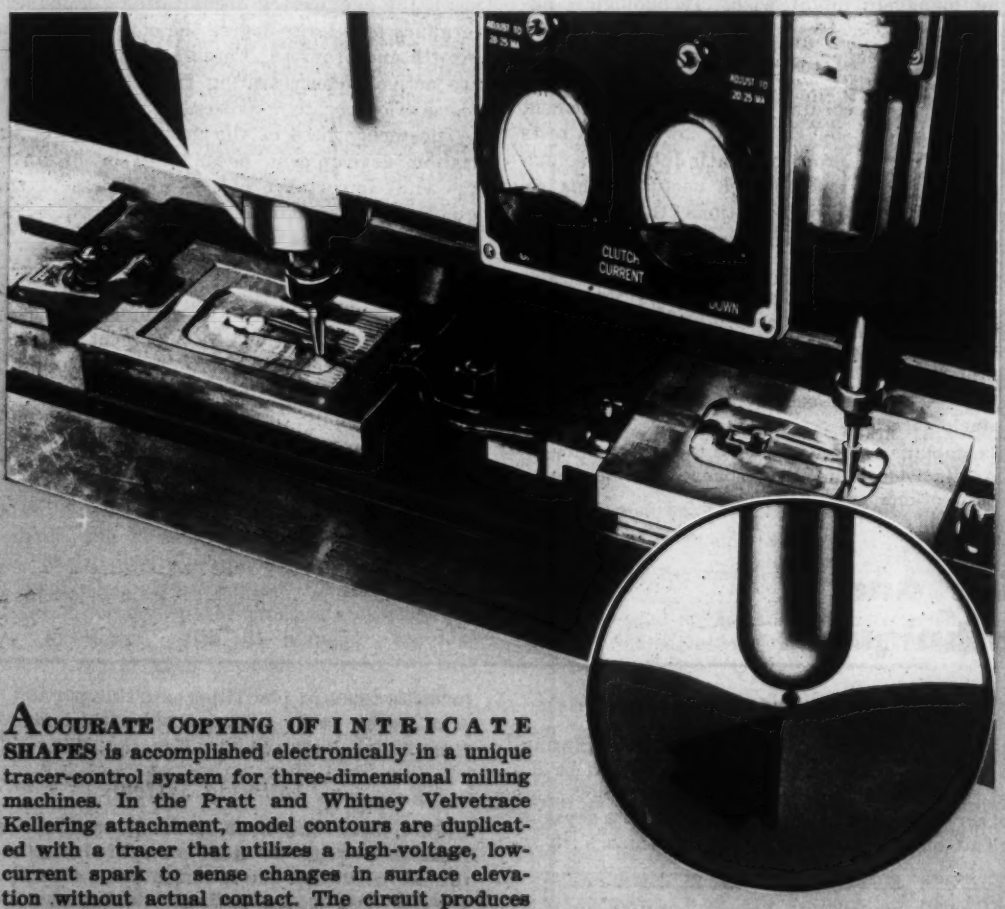
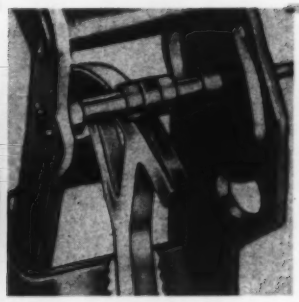


ACCURATE COPYING OF INTRICATE SHAPES is accomplished electronically in a unique tracer-control system for three-dimensional milling machines. In the Pratt and Whitney Velvetrace Kellering attachment, model contours are duplicated with a tracer that utilizes a high-voltage, low-current spark to sense changes in surface elevation without actual contact. The circuit produces a minute spark of constant length between tracer point and the electrically conductive, grounded model. The slightest variation in the spark gap produces a proportional change in voltage across the gap. This voltage change is instantly amplified electronically and is used to control spindle-quill motion through a specially designed magnetic-clutch drive.

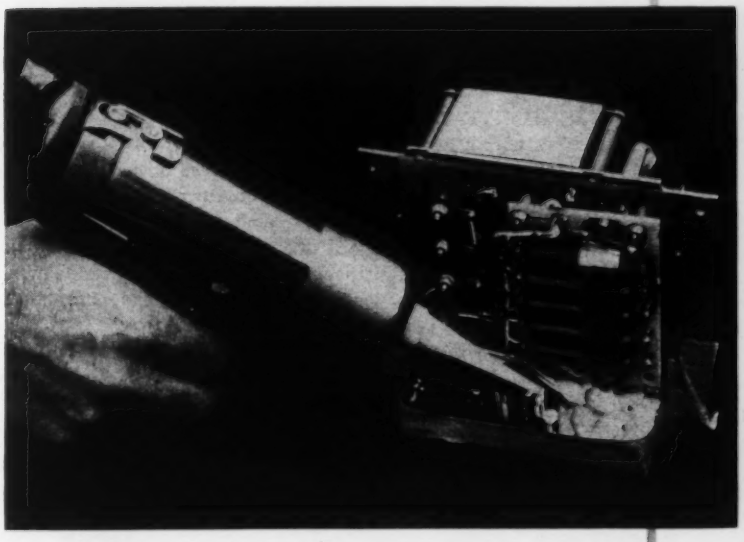
Anticipation circuits, which measure the rate-of-change of extremely small gap-length variations, are used to improve stability, accuracy and speed of response. The system automatically and continuously corrects tracer position to maintain a constant gap length between tracer point and model.

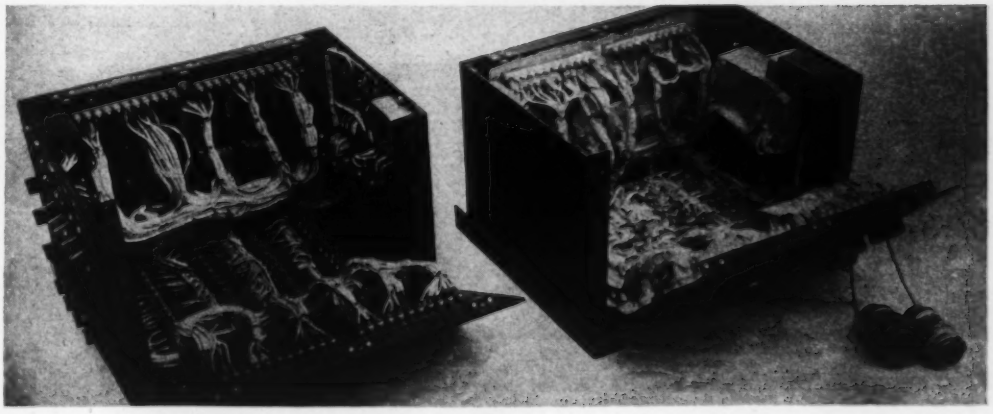


POSITIVE CONTROL OF LINEAR MOTION is provided in Norden-Ketay's Bandrive pressure gages. Deflection of the Bourdon tube or pressure cell is transmitted by a constant-force flat spring. In operation the pressure cell actuates the sector through a connecting link. Motion of the sector is transmitted to the pinion through the spring band. This linear motion is converted to responsive pointer rotation in ratio of pinion radius to sector radius.

The design eliminates backlash and lag between force-transmitting elements. The unit does not require a conventional hairspring return, since the constant-force spring is self-restoring.

SPRAY-ON "POTTING" TECHNIQUE for electronic assemblies simplifies protective sealing of units and permits inspection of individual components after assembly. At Northrop Aircraft Inc., interiors of aircraft electronic units are coated with Silastic RTV, a silicone rubber that cures at room temperature. A malfunctioning component may be removed by simply slitting open the rubber. After the component is replaced, the slit is patched with the same material.





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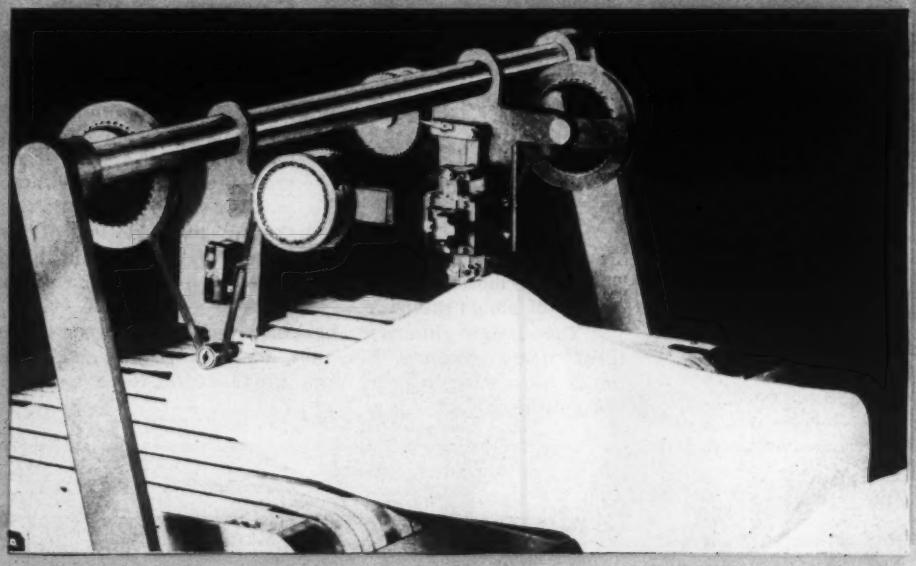
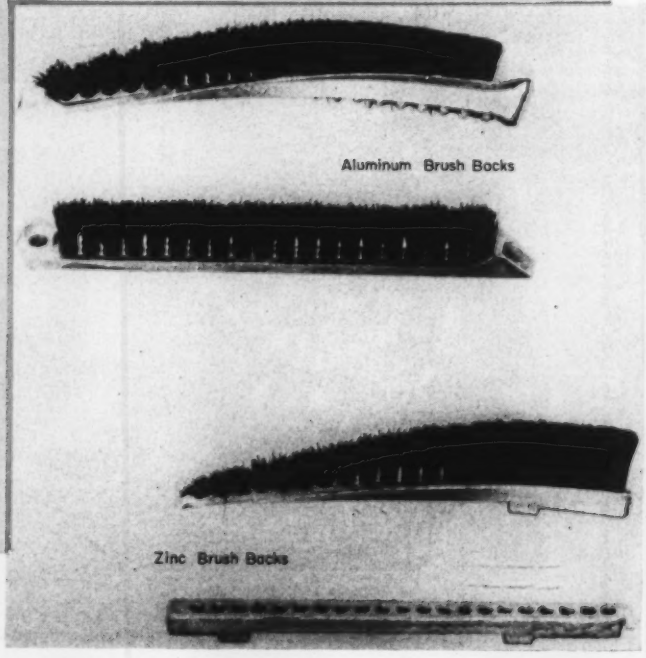


ADHESIVE-TAPE PICK-UP MECHANISM facilitates automatic handling of fabric and similar materials in machines and process lines. The design is applied in the Sharon Auto-Feed, a feeding device developed to pick up textile articles one by one from a pile and drop them accurately in a different position.

Manufactured by Sjostrom Machine Co., the unit consists of two pick-up heads mounted on arms that swing from the top of a pile of textile articles to a dropping position over conveyor belts or feed rollers. Each pick-up head contains a wind spool and an unwind spool. Adhesive tape is held under tension between these spools and around a roller that makes pressure contact with the textile material. When the pick-up heads move to the drop position, solenoids push the article from the adhesive-tape contacts. At the same time, a ratchet turns a spool advancing the adhesive tape enough to provide a fresh surface for contact with the next article.

COLD - FORMED DIE CASTINGS offer a new approach to design of metal parts with "twisted" contours. Brush backs for agitators in Hoover electric cleaners are cast straight, bristles are anchored in the holes, and castings are twisted approximately 115 degrees to the required helical contour by a cold-forming operation. Although an extra forming operation is actually required by the method, no machining is necessary on the cored holes.



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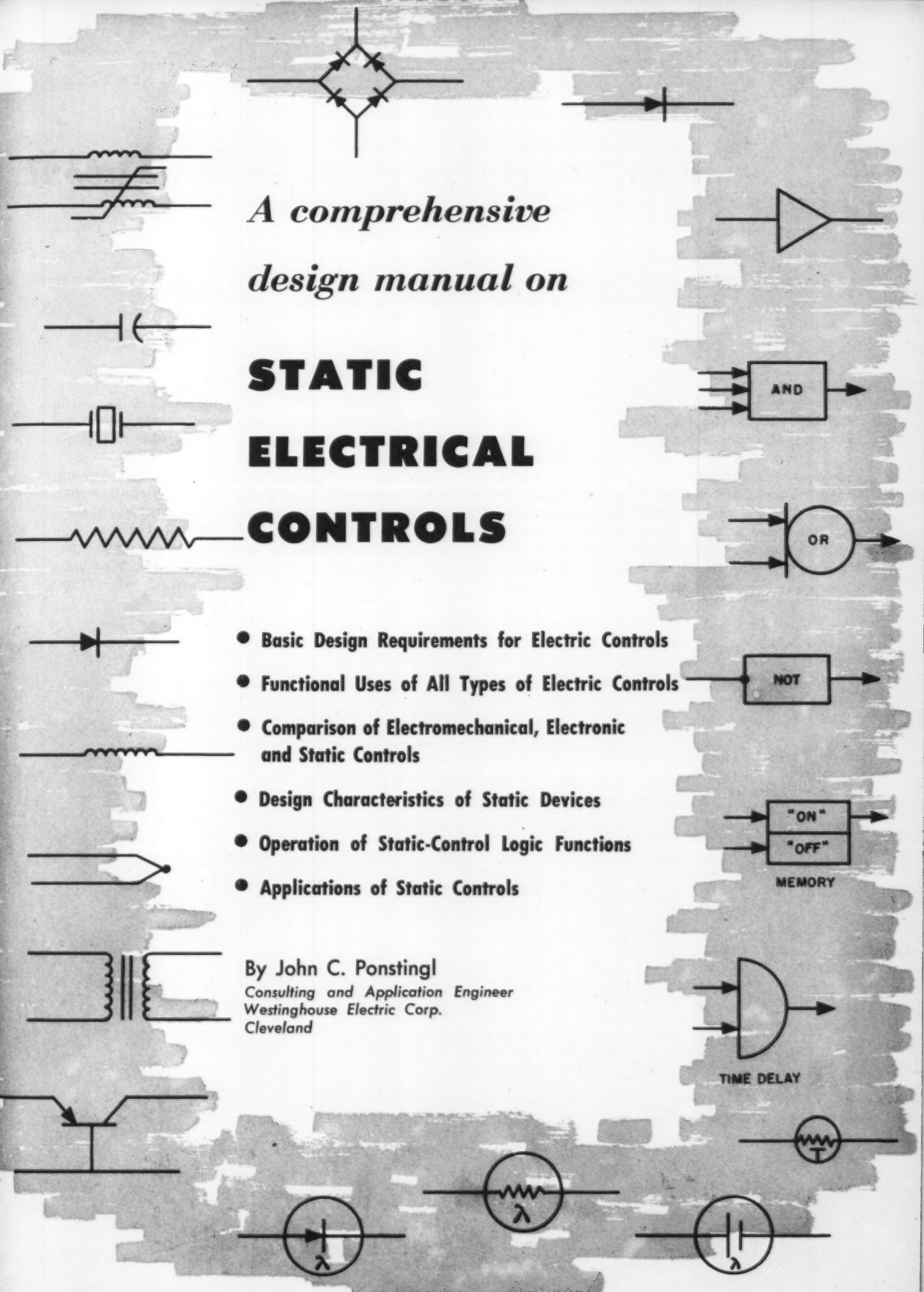
A comprehensive design manual on

STATIC ELECTRICAL CONTROLS

- Basic Design Requirements for Electric Controls
- Functional Uses of All Types of Electric Controls
- Comparison of Electromechanical, Electronic and Static Controls
- Design Characteristics of Static Devices
- Operation of Static-Control Logic Functions
- Applications of Static Controls

By John C. Ponstingl
Consulting and Application Engineer
Westinghouse Electric Corp.
Cleveland



What the designer should know about

INCREASED reliability and decreased maintenance at a reasonable cost are paramount design requirements today in electric controls for machines and equipment of all types. Failure of controls cannot be tolerated in many applications—in complex automatic-control systems for industrial machines and processes; in aircraft—guided missiles, jets, rockets, satellites; in nuclear-powered ships and submarines. A design solution to this problem is the use of electric controls constructed entirely of static electrical components, such as resistors, dry type rectifiers, saturable reactors, etc., Fig. 1.

Static electrical components have the obvious advantage of no moving parts, no contacts to wear, no filaments to burn out or deteriorate. A further advantage exists with the rather recent developments of practical static devices that can amplify and perform logic, such as the Westinghouse static controls trade named Cypak (from

Fig. 1—Below—Typical electrical controls constructed with static components—resistors, dry type rectifiers, and inductive-reactor elements.

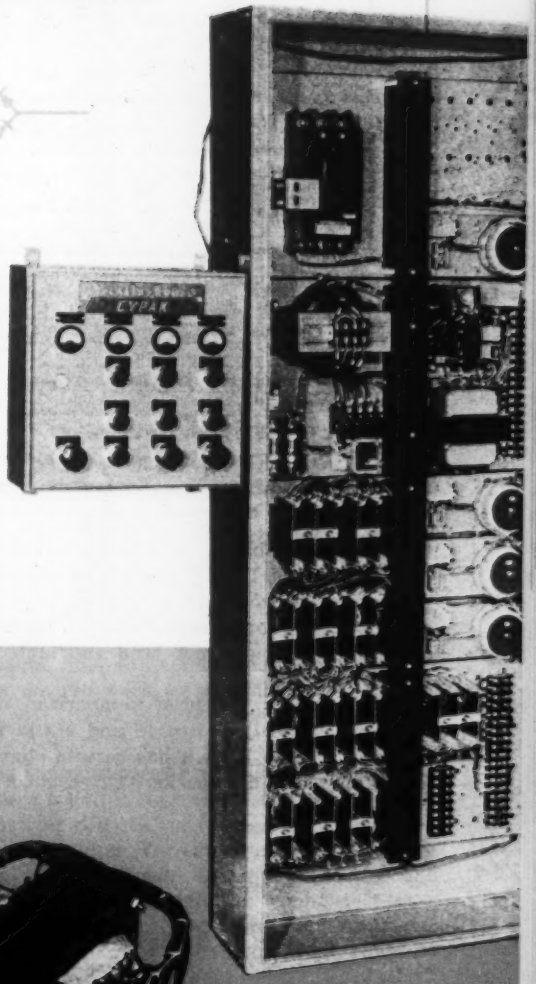
Fig. 2—Right—Static logic-element module before and after encapsulating in plastic. This plug-in design makes it easy to assemble control circuits and later to test circuits in the event of a malfunction.

Static Electrical Controls

packaged cybernetics). A typical static-control logic module before and after potting the components in plastic is shown in Fig. 2.

Static control devices have become practical realities because of the advances in magnetic materials, such as Hypernik and Alnico, and the recent improvements in semiconductors—transistors, germanium and silicon diodes, etc.

Combining the logic elements with other static electrical components permits the design of prac-



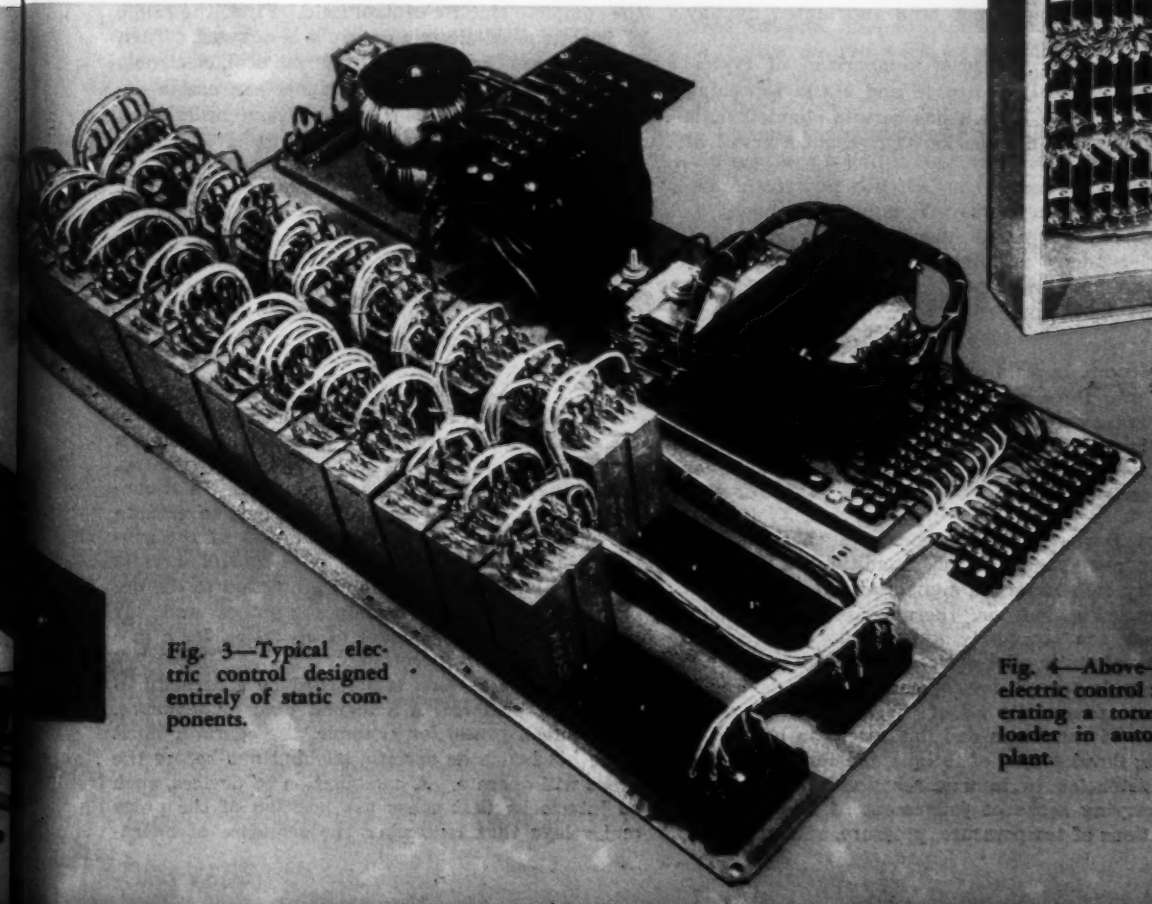
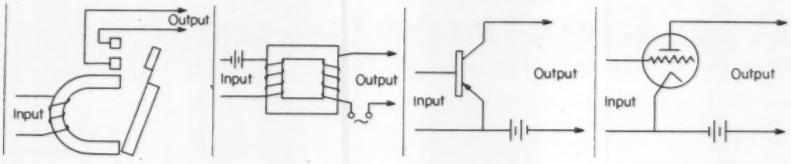


Fig. 3—Typical electric control designed entirely of static components.

Fig. 4—Above—Static electric control for operating a torus vane loader in automotive plant.

Table 1—Comparison of Switching Devices for Pilot-Control Circuits



Characteristic	Relays	Magnetic Elements	Transistors	Electronic Tubes
Size	Medium	Medium and large	Smallest	Small and medium
Temperature sensitivity	Minimum	Minimum and medium	Considerable	Minimum
Number of inputs and outputs	One or few inputs, many outputs	One or many inputs, one output	One input, one output	One or two inputs, one output
Speed of response	10 to 100 milliseconds	1 to 200 milliseconds	0.01-millisecond	Fastest—practically instantaneous
Reliability (life)	Fair—10 to 20 million operations	Best	Good	Fair and good
Voltage operating level	High and low	Low	Low	Medium to high
Efficiency	Fair	High	High—98-99%	Low to fair
Input power required	High and medium	Medium and small	Small	Low to zero
Current flow	Nonreversible	Nonreversible	Reversible	Nonreversible
Output wave shape	No change	Considerable change—introduce harmonics	No change	Depends on tube and circuit — high fidelity in some cases

tical, high-reliability, low-maintenance electrical control systems, Figs. 3 and 4. Of course, electromechanical devices, such as contactors, relays, etc., and electronic components, such as vacuum tubes, ignitrons, etc., have not been supplanted by any means.

As shown by the brief comparison of typical electromechanical, electronic and static switching devices in Table 1, each has certain characteristic advantages and drawbacks. Often some or all of these basic electric control components can best be used in combination, at least at this stage of development of the control art.

This article shows how static controls fit into the complete electric control field. First, the range of functions of electric controls is covered. Then discussed are the basic electromechanical, electronic and static components the designer can use in designing controls or can specify when ordering a control system for a machine.

Functions of Electric Controls

The complete field of electric controls can be divided into three major groups: (1) pilot devices, (2) pilot-control circuits and (3) power controls. The chart in Table 2 shows static type electrical components and circuit control functions that they can handle.

Pilot Devices: Sensing elements that measure and/or convert an action, condition or physical quantity into electrical signals are known as pilot devices. Pushbuttons, thermostats and pressure switches are commonly known pilot devices. A number of static pilot devices are shown in Table 2.

The wide spread development of pilot devices to duplicate practically all of the senses came about because of variations and limitations in human response; development of fatigue, tension, monotony; inconsistencies in human reactions; inaccuracies and varying sense of judgement of humans; and limitations of temperature, pressure, vibration, etc., that a person can tolerate.

Pilot-Control Circuits: These circuits perform the information processing of electrical signals produced by pilot devices. This includes switching, combining, amplifying and reducing. Pilot-control circuits provide the proper signals to actuate the power control or output members of the system. The main functions of pilot-control circuits are to (1) provide safety and protection to the operator and the driven machine or process and, (2) provide a definite sequence of operation for a machine, process, or operation.

Safety to personnel is afforded by control functions that perform in a logical plan or sequence. On a punch press, for example, the operator must place his hands on specific pushbuttons before the press will operate. A combination of devices, such as interlocks that sense the position of the press and relays that remember the sequence of opera-

tions, insures only one operation of the press.

Interlocks on elevator doors that sense the position of the door prevent movement of the elevator until the doors are properly closed. Timing devices control the acceleration of traction motors on trains.

Protection for driven machine and drive is often a design factor. Overload relays sense the temperature rise in electric motors and remove power when the danger zone is reached.

Interlocking on a machine tool insures that the lubricating oil pressure is up, the coolant is flowing, and a work piece is properly positioned before the cutting tool goes into operation.

Definite sequence in operation, in a bottling machine for example, is achieved through co-ordination of sensing temperature, pressure, position, etc.

The information processing in a pilot-control circuit may range in complexity from a simple comparison or combination of several signals, such as pushbuttons and overload relays on a motor starter, to involved sequencing operations or regulatory processes involving feedback and compensating signals from both the input devices and the output power control. Usually, the power level at which this electrical information is processed will be quite low (in the order of watts or a fraction of a watt) and independent of the power level of the equipment being controlled. A 100-horsepower motor drive may require 500 watts or less of pilot-controlled power.

Information or signal inputs to a pilot-control system may be digital—in the form of discrete states or levels of electrical quantities, such as *on-off* as produced by a pressure switch or pushbutton—or analog—a continuously variable quantity, such as produced by a tachometer generator where the electrical output signal is proportional to the speed.

Digital processing usually involves relays and other switching means that are of the *on* or *off* type. On a punch press or elevator, it is either safe to operate or it isn't. A motor is running or it isn't, or it runs forward or reverse or fast or slow. Lights are on or off, etc. Where many combinations of conditions must be grouped in logical order, a digital system proves the most positive.

In the analog category it may not be desirable to have decisions or results so definite. A range of control may be desired. The output of a heater may have to be continuously adjustable rather than *on* or *off*. Here pilot-control circuit elements are identified as amplifiers, integrators, multipliers, bridge circuits, and regulators.

High-speed process lines often employ control circuits operating from continuously varying signals, such as speed-sensing tachometers, so that control changes of only the desired amount will be made. As in a shower, fine adjustments in hot and cold water must be made whereas, in drawing a bath, *on-off* adjustments can be made to produce a given water temperature. Actually an analog system can be considered as an infinite number of digital signals.

Power Controls: These controls connect the electric power to the electric motor, solenoid, heater, or whatever the device may be that converts the electric power to some useful form.

In the development of the control art, power controls came first. The immediate job was one of connecting the electric power to the device—motor, lamp, etc. Initially, manually operated mechanical or electromechanical devices, such as knife switches and the like, were the only controls employed. Soon human power was replaced by magnetically actuated switches like contactors and manually operated pilot devices, such as a pushbutton to control the contactor from a remote point. This technique afforded considerably more safety to the operator.

Although pilot devices and pilot-control circuits always have a power control associated with them, power controls are still often used by themselves. A house light switch, for example, is a power control in its simplest form. Often pilot devices and power controls are one and the same, such as a simple furnace thermostat. Here the thermostat responds to a temperature signal and connects electric power to a fuel-solenoid coil.

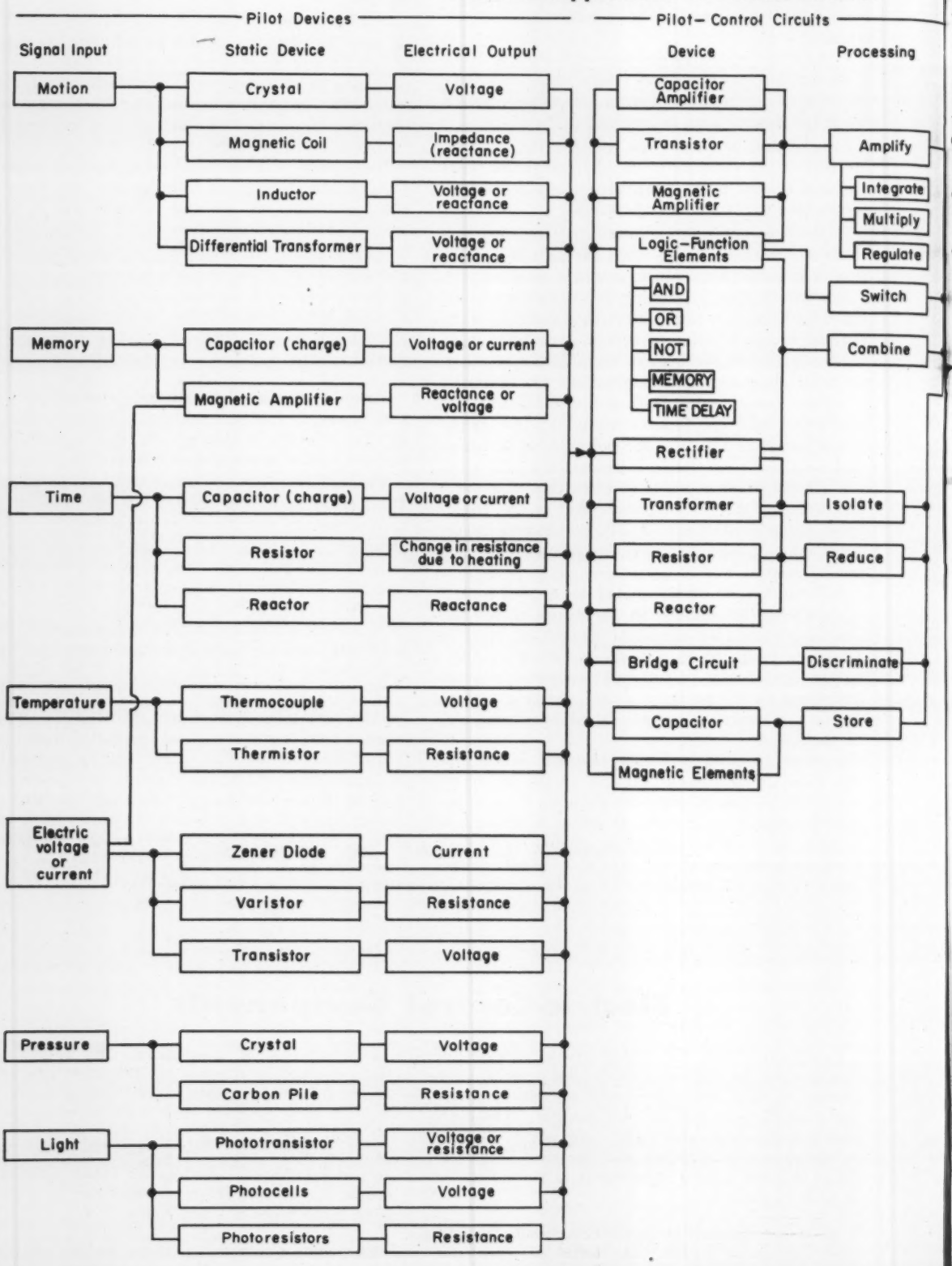
Electric-Control Components

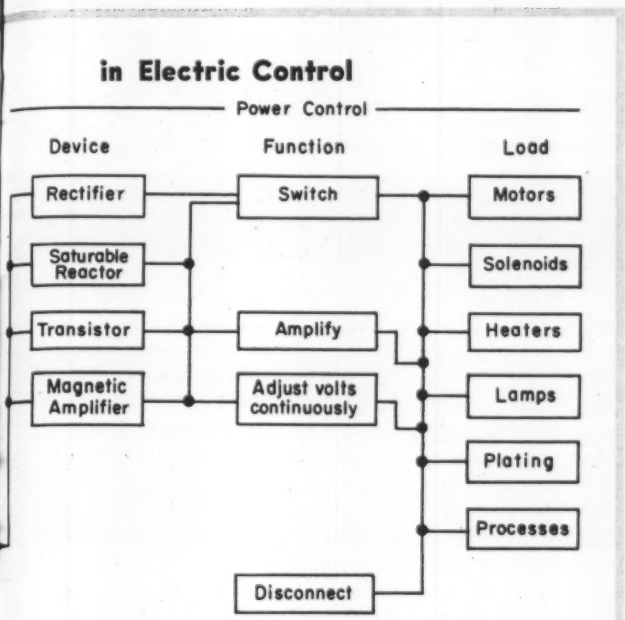
Components that have been developed over the years to fill the design needs of pilot devices, pilot-control circuits, and power controls can be classified into three rather distinct families. These are electromechanical, electronic, and static devices. A comparison of physical and electrical characteristics of some typical components in these families is made in Table 1.

Electromechanical Devices: This family includes such devices as pushbuttons, knife switches, contactors and relays; these came first in the development of control components. By comparison, electromechanical devices are the least expensive. Significant characteristics are moving parts associated with contacts that mate to complete an electrical circuit. The parts are moved either manually or by means of magnets, motors, air or oil pistons, bimetal devices or other motivating means. Complete control systems can be designed using these types of components.

Electronic Controls: In these devices electricity is conducted through gases, a vacuum or vapors

Table 2—Application of Static Devices





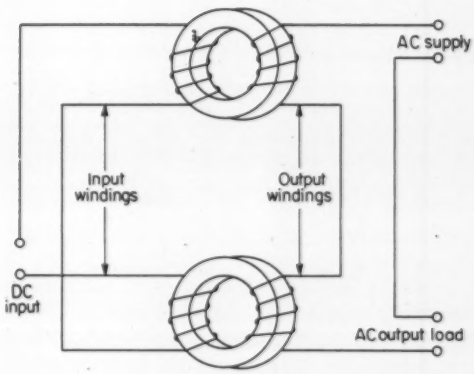


Fig. 5—Typical saturable-reactor circuit for controlling ac power. Two identical reactors are used with dc windings connected in opposition to neutralize the induced ac voltage developed by output load windings.

and is controlled in that state. All electronic control devices for that reason are housed in some type of container, such as a glass or metal bulb. The device may include within the bulb two elements, as in a diode, where the electricity flows through the gas from one electrode to the other electrode; or an electronic component may contain many elements, such as cathodes, filaments, control grids and plates to perform a variety of control operations.

Various electronic devices are generally assembled with static control devices in the form of resistors, capacitors and dry-type rectifiers, as well as switches, to make up a complete system.

Static Electric Controls: In construction these devices are solid in state and essentially do not depend upon a movement of parts to perform a control function. Typical static electric control elements are capacitors; crystals; reactors, including saturable reactors; rectifiers or semiconductors which include the copper-oxide, selenium, silicon, germanium, titanium-dioxide types; resistors; thermocouples; thermistors; transformers including autotransformers; transistors including photosensitive types; and varistors (Thyrite).

Design Applications of Static Controls

As shown in Table 3 each static component has certain characteristics that fit needed functions in the control of electricity. Electric-current switching and/or control is performed within a solid material.

In one sense, control may occur through the natural characteristics of the device. For example, in a dry type rectifier current flows freely (conductor characteristic) in one direction and is relatively restricted (insulator or resistor characteristic) in the opposite direction. This is an important function used in pilot-control circuitry.

In another sense, control may occur as a result of external influences from a magnetic flux, voltage, pressure, temperature, etc. Most pilot devices fall in this category, although it also applies to elements in pilot-control circuitry and power control.

Many static components can also be combined to perform functions other than their own specific characteristics. For example, bridge circuits, logic elements, and magnetic amplifiers have been developed to satisfy specific control needs in the application of electricity.

Saturable Reactors for AC Power Control: In the past, saturable reactors have been used quite effectively for controlling the power from fixed-voltage to resistance loads, such as theater lights and electric furnaces, etc. As shown in Fig. 5, a saturable reactor is basically a varying reactance in series with the power supply and the load. In its simplest form, two coils are wound on an iron core. The ac winding represents the load reactance and the dc winding controls the degree of core saturation. Normally two identical reactors are used, and

the dc windings are connected in opposition to neutralize the induced ac voltage that appears by transformer action from the ac load windings.

When the dc control current is at a minimum or zero, the impedance of the output or ac load winding is high. The load current and voltage are small with practically the full ac supply voltage appearing across the reactor.

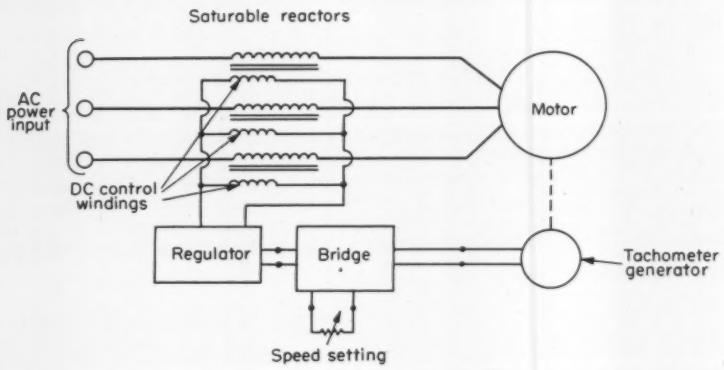
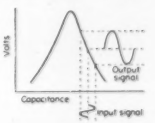
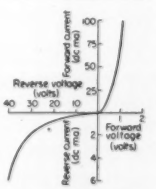
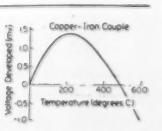


Fig. 6—Saturable-reactor circuit designed for controlling speed of a high-slip, three-phase squirrel-cage motor.

Table 3—Characteristics and Applications

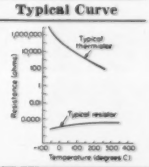
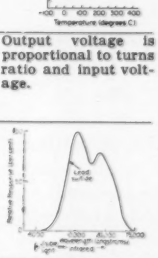
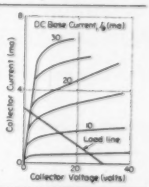
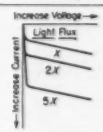
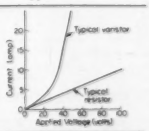
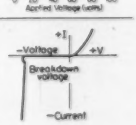
Static Component	Design Characteristics	Control Features	Applications	Typical Curve
Capacitor	Constructed with two conductor plates insulated from each other by dielectric. On dc, used for electricity storage. On ac, used as a shunt load or negative impedance in a series circuit.	On ac, impedance varies inversely with the frequency. On dc, the larger the capacity, the longer the timing period. The higher the load resistance, the longer the discharge time.	Power-factor correction, timing circuits, electricity storage, minimize contact arcing.	See features
Capacitor (Voltage-sensitive with ferroelectric dielectrics)	Has a ferroelectric dielectric with nonlinear characteristics so that capacitor is sensitive to changes in applied voltages.	Capacitance changes as the applied voltage increases, giving an amplification of capacitor current.	Dielectric amplifiers, switching and control circuits, modulator circuits, and flip-flop circuits.	
Crystal (Quartz or Rochelle salt type)	If a mechanical tension or compression is applied to the crystal along its y-axis, the material becomes electrically polarized along its x-axis. Materials such as quartz, borium silicates and Rochelle salts are used.	The element operates as a reversible transducer; if a vibration is applied, a voltage develops. If a voltage is applied, a vibration or movement occurs.	Deflection and strain gages, microphones, pressure indicators, frequency references, loudspeakers, and ultrasonic motors.	Voltage output is determined by the amplitude of vibration.
Reactor	A coil or winding on an air core or iron core that imposes an impedance to the flow of ac current.	Impedance varies directly with the frequency. An iron core increases the impedance to the flow of ac current or the build-up of dc current.	Current-limiting; used in conjunction with capacitors for resonant or tuned circuits.	See features
Rectifier (Metallic)	A junction point or surface of a specially treated material (copper-oxide, selenium, germanium) that permits the flow of current more easily in one direction than in the other.	Current flow is restricted in reverse direction until the voltage is raised to the breakdown point which varies from 5 to 50 volts depending on the type of rectifying material. Plates or junctions can be put in series for higher voltages.	Rectifying, switching isolating of currents.	
Resistor	Has characteristics between an electrical conductor and insulator. Current flow is essentially the same when flowing in either direction.	Resistance increases with temperature increase. Resistance is directly proportional to the length of the conductor and inversely proportional to its cross-sectional area.	Current-limiting, voltage-dividing.	See thermistor and varistor
Thermocouple	Junction of two different metal wires. Develops voltage at free ends due to temperature gradient.	Can be operated over temperature ranges from −300 F to +1600 F. Typical wire combinations are iron-constantan, copper-constantan, Chromel-Alumel.	Temperature-sensing devices, pyrometry, radiation detection, thermoammeters.	

When the dc control current is increased to the point where the iron core is saturated, the impedance of the ac winding is reduced so that full-load current can flow through the load; practically the full supply voltage now appears across the load. Between the limits of the minimum and maximum dc control current, the load voltage and current are continuously adjustable. More power can be handled by the ac winding than is required in the control winding. As a rule of thumb, the control power can be 1 per cent of the output power. In a typical example the impedance or resultant voltage drop across the ac winding can be as low as 2 to 3 per cent of the rated ac voltage at saturation. At no saturation the impedance may be 50 or 100 times as great.

Smaller-sized saturable reactors are used to provide adjustable phase-shift control of electronic thyratron tubes.

Saturable Reactors for Speed Control: Saturable reactors can be used effectively for controlling the speed of a high-slip, three-phase squirrel-cage motor. Three reactors are placed in series with the power lines to the motor. To compensate for speed changes caused by varying motor loads, the basic scheme shown in Fig. 6 is employed. The voltage from the tachometer, which represents motor speed, is connected to a regulator system; this regulator controls the amount of dc excitation needed on the saturable reactors to maintain a constant motor speed. A bridge circuit that balances the tachometer output against a speed-setting reference provides the intelligence for obtaining different motor speeds from approximately 85 to 90 per cent of motor synchronous speed down to approximately 15 per cent of motor synchronous speed. The regulator can be a magnetic amplifier or an electronic type amplifier with fairly good speed regulation. The speed of response of the regulating system will be determined by the time constant of the dc windings on the saturable reactors as well as the regulator and drive-system characteristics.

of Static Electrical Control Components

Static Component	Design Characteristics	Control Features	Applications	Typical Curve
Thermistor	Resistance material having a large negative temperature coefficient of resistance. The resistance of a thermistor decreases as the temperature rises and increases as the temperature falls.	Over a temperature range from −50 C to +200 C the resistance of thermistors decrease by a factor of 10,000 while copper increases by a factor of 2. Typical resistance is 50,000 ohms at room temperature.	Temperature measurement and control, safety and warning circuits, regulators, temperature compensation.	
Transformer	Consists of two reactors wound on one iron core. One winding is energized (primary). The second (secondary) winding will have a voltage induced in it.	Practically no limit to transformation ratios, or power-handling capacities.	Transforming voltages to other value, isolation of circuits, phase reversals, harmonic generators, voltage control.	Output voltage is proportional to turns ratio and input voltage.
Transistor	A semiconductor device similar to a diode but having a third element that can be used to control the rectifying or conducting characteristic.	Some transistor properties vary with temperature. Controls power with an efficiency of 98 to 99 per cent. Essentially a low-voltage device.	Used in amplifier circuits, rectifier circuits, and as a switch.	
Phototransistor	Depending on the type, light shining on the junction or sensitive portion produces a voltage or change in resistance.	Small size, low power consumption and operating voltage, high sensitivity, rugged. Is sensitive to temperature changes. Voltaic cell type generate approx. 1/10 voltage in response to light.	Light-beam type controls, limit switches, counters, protective devices, infrared detectors, lightmeters, applying sound-on-film, optical IBM punch cards, etc.	
Cadmium-Sulfide and Lead-Sulfide Photo-Cells	With no light shining on the cell, it is essentially an insulator. When light shines on the cell, electrons are freed permitting the conduction of electricity when voltage is applied.	A cell ⅛-inch square can control ¼-watt of electrical power. Ratio of light to dark resistance may be 100,000 to 1.	Infrared lead-sulfide light-beam applications, detection light-beam telephones, and telegraphing cadmium sulfide for radio activity measurement.	
Varistor (Silicon-carbide resistance, Thyrite)	A nonlinear resistance material in which the current varies as a power of the applied voltage. As the applied voltage increases, the resistance decreases.	Doubling the voltage applied to a varistor may increase the current by a ratio of 10 to 100 depending on the unit used. In contrast, in a linear resistor, the current is only doubled.	Voltage-surge protectors, lightning arresters, automatic voltage control.	
Zener Diode (Silicon or germanium junction type rectifier)	Same operation as dry type rectifier except a junction point is used; small junction diode (point contact).	Junction type rectifiers produce a marked cutoff point when reverse voltage is applied.	Voltage-sensing applications.	

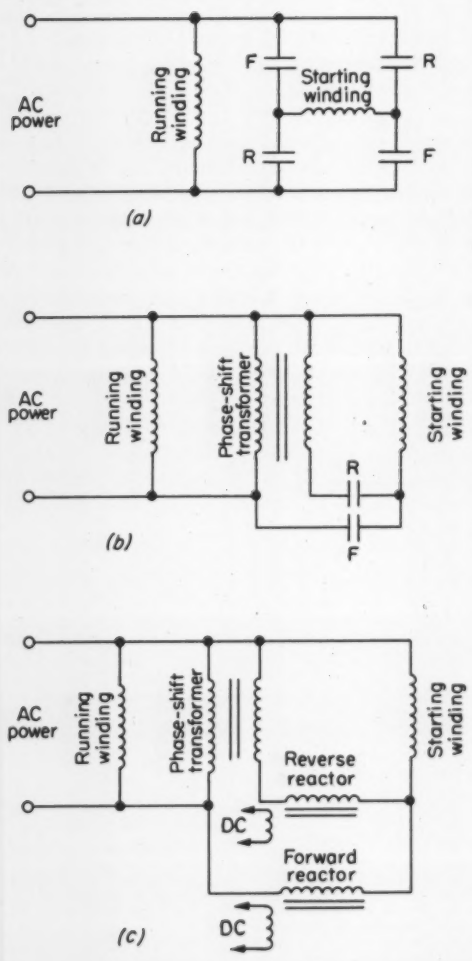


Fig. 7—Three methods of reversing a squirrel-cage motor. In *a* is circuit using reversing four contactors, whereas in *b* motor reversal is accomplished with two contactors and a phase-shift transformer. In *c* is a circuit using a phase-shift transformer and dc controlled forward and reverse saturable reactors.

Saturable Reactors Replace Reversing Contactors: An effective use of saturable reactors can be made in replacing the set of reversing contactors on an ac squirrel-cage motor control. Fig. 7*a* illustrates a simple single-phase reversing control using contactors. Contacts F are closed to start the motor in the forward direction. To reverse the motor, the phase of the starting winding or running winding must be reversed. This is effectively done by opening the F contacts and closing the R contacts.

Step one in developing the saturable-reactor control for reversing is to use the principle that the secondary of a transformer is 180 degrees out of phase or is the reverse of the primary. The connection or phase to the starting winding is effectively reversed as shown in Fig. 7*b* by closing contact R to produce reverse motor rotation; closing contact F energizes the motor for forward rotation.

Although saturable reactors do not provide 100 per cent *on-off* operation, they can effectively replace the function of contacts F and R, as depicted in Fig. 7*c*. When the *forward* reactor is saturated, the motor starts in the forward direction. When the *reverse* reactor is saturated, the motor starts in the reverse direction. This scheme also applies to a three-phase motor. As a further refinement, proper proportioning of dc excitation in the two reactors on a three-phase motor application, which produces both forward and reverse torques with one predominating, can develop very low motor speeds—approximately 5 per cent of rated speed. This design makes it possible to use a three-phase ac motor as a positioning device where creeping speeds are required as well as normal speeds.

Saturable Reactors for Wound-Rotor Motor Control: This basic reactor-reversing power control has been applied to wound-rotor motors on many severe-service applications, such as material-handling cranes and lift-bridge drives of 200 horsepower and larger. Most of the speed and reversing control is performed by the static reactor control, eliminating the normal wear and maintenance required with contactors.

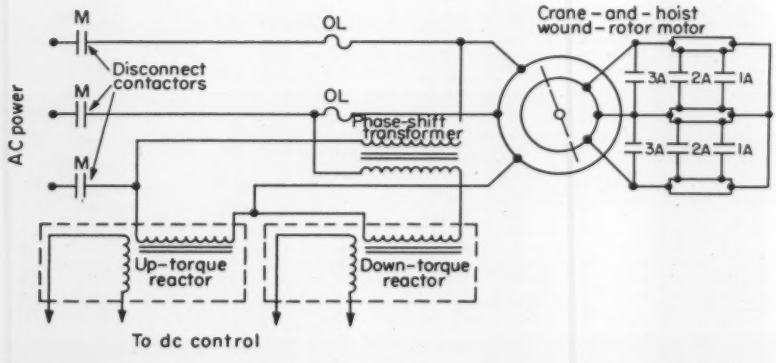


Fig. 8—Static-reactor speed control system for a three-phase wound-rotor motor. Combination use of contactors for complete disconnect and static reversing control offers design advantages of both.

A typical control, Fig. 8, employs a line contactor to provide complete line disconnect since the reactor itself does not give complete cut-off. Here is an example of co-ordination of an electromechanical and a static device, using the good features of both.

Special Resistors for Automatic Control: The silicon-carbide varistor is used as an automatic volume control on telephone receivers because of its natural characteristic of having a higher resistance at low voltages than at relatively high voltages.

The Thyrite (another silicon-carbide type) resistor can be used as an automatic protection across a dc motor field circuit because it automatically provides high resistance at normal line voltage and low resistance when the applied voltage is increased, for example, during the discharge of the field circuit. The change in a typical Thyrite resistor is such that it will conduct 16 times more current for each doubling of the applied voltage.

Circuit Selection with Rectifiers: An important function of dry type rectifiers is in isolating circuits as well as combining circuits in a dc or unidirectional (half-wave) ac pilot-control circuit. For example, in Fig. 9*a* pushbutton 1 energizes relay coils A and B, but pushbutton 2 energizes only coil B. Pushbutton 1 must be a two-pole unit to isolate coil A and B. If an extra contact exists on relay A, then either of the circuits in Figs. 9*b* or 9*c* can be used. In this case, both pushbuttons are single-pole units. Fig. 9*d* illustrates the use of a rectifier to isolate coil circuits A and B. In this case, the second pole on the pushbutton as well as the extra relay contact A are eliminated. In a pilot-control circuit involving a large number of contacts, this technique can save many contacts. This is a technique employed in Cypak or logic functions, explained later.

Contactless Limit Switches: Proximity type, con-

Fig. 9—Four circuits in which pushing pushbutton 1 energizes coils A and B, whereas pushbutton 2 energizes only coil B. Circuit *a* uses a two-pole pushbutton to isolate coils A and B. Circuits *b* and *c* use an extra contact on relay A. Metallic rectifier in circuit *d* provides current combining as well as isolating.

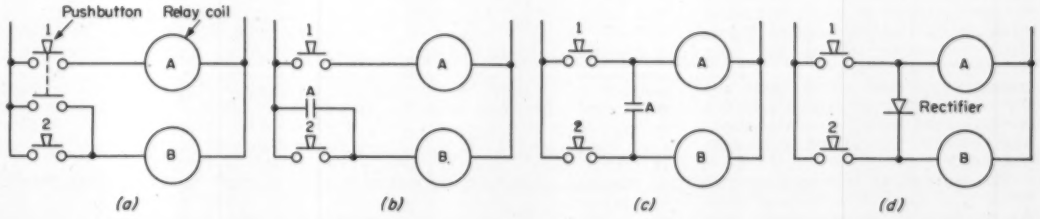
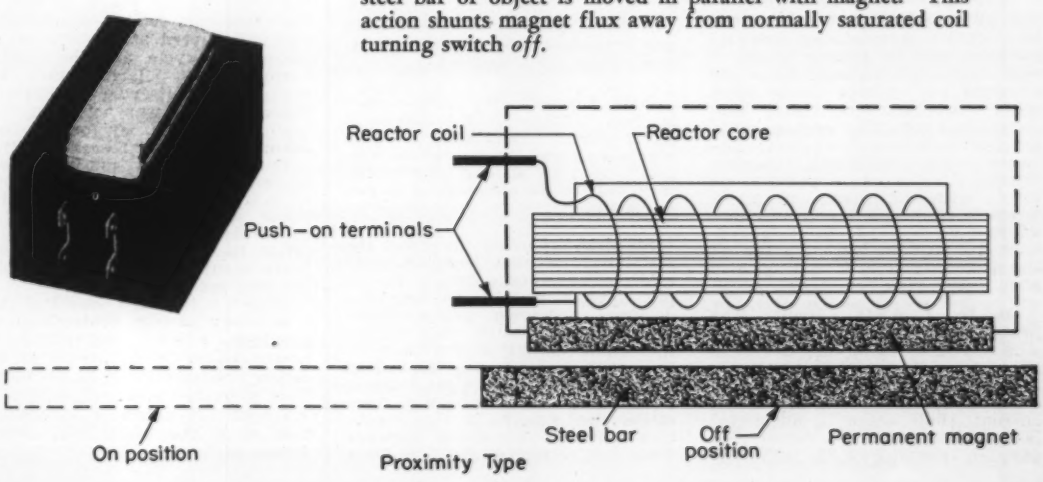


Fig. 10—Contactless limit switch design. Unit is *on* unless steel bar or object is moved in parallel with magnet. This action shunts magnet flux away from normally saturated coil turning switch *off*.



tactless limit switches operate on the principle of change in impedance of a coil. In a typical design, Fig. 10, a reactor and permanent magnet, stationary with respect to each other, are completely encapsulated in a single unit that is mounted on a fixed rigid section of the machine it is to control. A bar of magnetic material is fastened to the moving part of the machine so that at the desired operating position the bar comes within 3/32-inch of the magnet, causing a magnetic shunting action that unsaturates the reactor core and produces, in effect, an electrical *on-off* function. At no time is there mechanical contact between the moving and stationary parts.

Circuit Design Theory and Operating Principles of

Magnetic-amplifier type logic elements employ the unique Ramey circuit which provides for fast response by the addition of a reset circuit. A second winding of N_R turns is added to the magnetic core, and a resistor R_R of such value that E_R will drive the core to saturation during a half cycle. However, the rectifier *CR*2 and the polarity of E_R are arranged so that the second winding N_R will drive the core to negative saturation during the half cycle that current flows.

During the first half cycle, called the gating half cycle, voltage E_G drives the core to positive saturation. During this half cycle, the flow of current in N_R is blocked by the rectifier *CR*2 in this circuit—the reset circuit. During the next half cycle, current in the gate circuit is blocked by the rectifier *CR*1 while voltage E_R in the reset circuit drives the core to negative saturation. With continued application of E_G and E_R, the core will oscillate between positive and negative saturation, and there will be virtually no output to the load.

The output of this system can be controlled. If the reset voltage E_R is absent for one reset half cycle, an output will appear across the load resistance on the next gating half cycle, because the core will remain saturated. A problem arises in finding the best way to prevent reset where an output from the circuit is desired. If it is desirable to drive the circuit by a voltage from other similar circuits, a relatively low resistance can be placed in series with the reset voltage. Then by supplying a voltage from some other source, the reset voltage can be blocked out. The proper value of resistance is a compromise between two conflicting requirements: (1) Low impedence in series with the reset voltage in order to reset completely with the voltage E_R and (2) High impedance to provide least loading of the preceding or driving stage and show some gain per stage.

One-Input AND Circuit: The problem encountered with circuit *a* is solved by using the circuit *b*. Bias dc voltages are introduced in both the gating and reset circuits. In the reset circuits, direct current (half wave is adequate) is applied so that the current, I_3, through rectifier *CR*3 is larger than I_R, which is the current that flows through the core and resets the core.

When an input voltage greater than E_R is applied, the current in rectifier *CR*3 tends to drop to zero, and the effective impedance of *CR*3 becomes its backward resistance—a very high value. Rectifiers *CR*2 and *CR*3 are blocked, reset current cannot flow, and an output appears across the load on the next half cycle. Thus, circuit *b* provides a one-input AND element, that is, one input to the element will produce an output.

The function of the dc bias in the gate circuit is to reduce the output to the load resulting from core exciting current. The rectifier *CR*4 presents a low impedance to exciting current flow, but a high impedance when the circuit is producing an output.

Two-Input AND Circuit: In the two-input AND circuit shown in schematic diagram *c*, it can be seen that rectifiers and dc bias voltage are provided for each of the input circuits. It is apparent in *c* that both inputs are required to develop an output. If either of the inputs is not present, reset of the core will be accomplished through the biased rectifiers *CR*3 or *CR*5.

Three-Input OR Circuit: Schematic *d* shows a three-input OR circuit that produces an output when there is an input to any one or more of the input terminals. The rectifiers *CR*1, *CR*2 and *CR*3 are introduced to provide isolation of the input signals.

NOT Circuit: The NOT circuit is very similar to the one-input AND circuit. The voltage E_R is eliminated, and the terminals normally used for E_R are used as the terminals to the element, as shown in circuit *e*.

MEMORY Circuit: In effect the MEMORY circuit is essentially an information storage device. An input applied at the *on* terminal develops a known output condition, which continues even though the input signal is removed. If an *off* signal is now applied at the other terminal, the circuit switches to a different output condition and remains in that condition, until an *on* signal appears. Two OR circuits are combined with two NOT circuits to provide the MEMORY function shown in circuit *f*.

If it is assumed that NOT circuit 1 is producing an output, this output resets the core in NOT circuit 2 through OR circuit 2. A half cycle later NOT circuit 2 produces no output. This NOT circuit 1 again resets core 2, with the result that this stable output condition is self-sustaining. The output is a half-wave voltage in phase with the supply voltage to NOT circuit 1.

A voltage of proper phase and magnitude applied to input 1 will reset core 1 through OR circuit 1. A half cycle later no output appears from NOT circuit 1. Since core 2 is not reset, a half cycle later an output results which is opposite in phase to the previous output. This output resets core 1 so that it will have no output on its gating half cycle. Even though the input is removed, the output remains stable in this condition. The output is shifted back to the original phase by introducing a voltage of proper phase and magnitude to input 2.

Storage of information is indefinite if the power supply voltages are not interrupted. Statistically there is a great likelihood that the stable state existing before a supply voltage removal will be present after the voltage is reapplied. The condition that will cause loss of the stable state occurs when the core normally being reset by the stable output of the other core has its supply voltage interrupted at the end of its gating half-cycle, and the voltage reapplied with polarities such that the gating half-cycle is repeated. Since the core was not reset during the interim, an output will occur. This output resets the other core which was normally saturated. Therefore, the output shifts from its former stable state to the other stable state just as if an input signal had been applied to effect the shift. This loss of stability occurs only if the input signal has been removed.

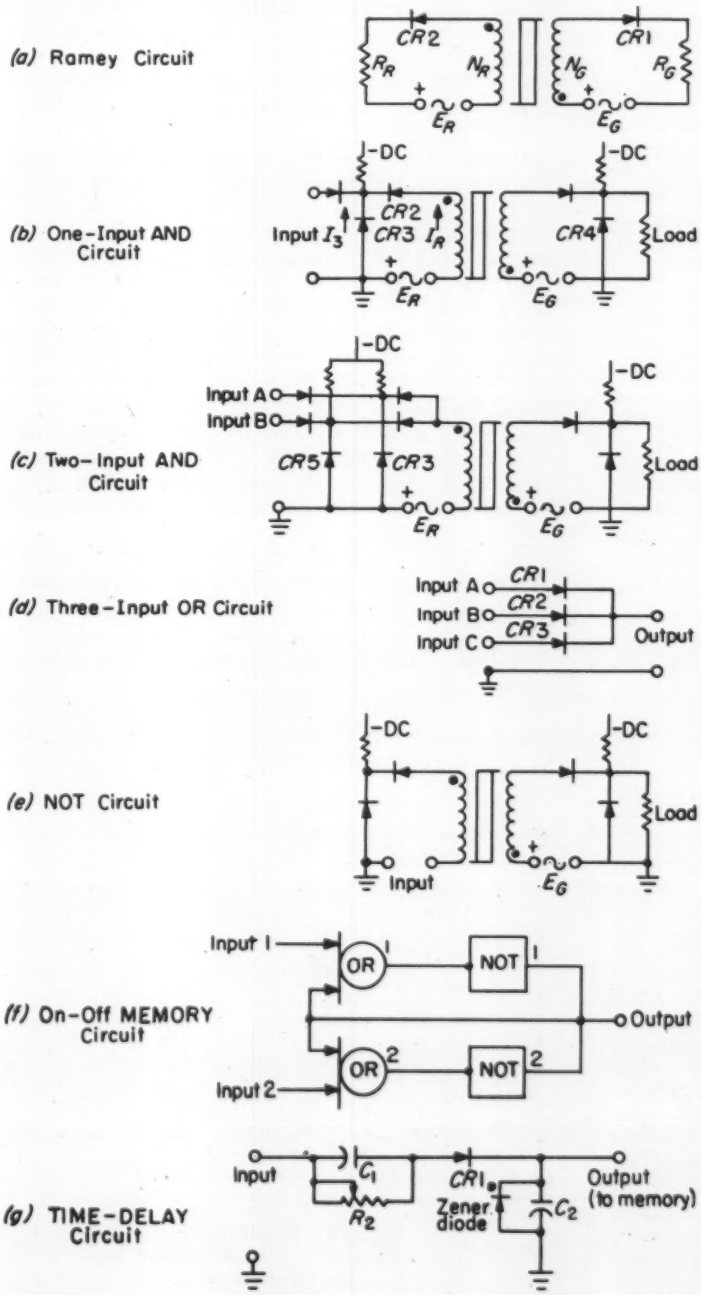
Where it is found essential that a memory circuit remembers its previous state, regardless of power-supply interruptions, an additional circuit may be included. This is termed a retentive MEMORY unit, and operates in connection with the MEMORY circuit shown in *f*.

Since the reactor coil itself operates at low voltage and develops negligible temperature rise, it will last indefinitely. In addition, the coil is immune to dirt, oil, moisture and mechanical damage because of the encapsulated construction.

Amplifying Techniques: Most static-sensing elements are of low-voltage, low-power output; therefore, magnetic amplifiers, transistors, and capacitor amplifiers are important items in expanding the art of static control systems.

MAGNETIC AMPLIFIERS: A magnetic amplifier is

Static Magnetic-Amplifier Type Logic Functions



TIME DELAY Circuit: Proper system operation frequently calls for a delay period between the time when an input signal is received, and the time that an output is produced. This result is obtained by the addition of a time-delay element to a MEMORY ciruit. Circuit *g* shows only the TIME-DELAY element, which feeds its output into input 1 of the MEMORY circuit in *f*.

The time constant of $C_1 \times R_2$ is short (a few cycles of the supply frequency at most); the time constant of C_2 and its load in the MEMORY circuit is long (about the same magnitude as the desired delay from the complete circuit). Capacitor C_1 has very small capacity compared with C_2. Therefore, application of a pulse to the input will divide the input voltage across the capacitors as the reciprocal of their capacities respectively with nearly all of the voltage across C_1 and very little across C_2. During the portion of the cycle where the input is zero, C_1 discharges through R_2. This discharge takes place independently of the rest of the circuit. The second pulse input repeats the preceding operation, except that the pulse amplitude is reduced by the amount of charge present on C_1 and C_2. As the pulse train continues, the charge on C_2 is slowly increased until sufficient current flows through terminal 1 to change the output state of the MEMORY circuit.

The charge on C_2 will continue to build toward the peak value of the input pulse after the delay has elapsed even though further increase in voltage has no effect on the output condition. Since this build-up in voltage results in a higher capacitor voltage rating than actually necessary to operate the circuit, a Zener diode is added to hold the peak voltage to a preset value. As the capacitor charge tends to exceed 6 volts, a discharge current will pass through the Zener diode, restoring it to the 6-volt level.

Discharge of C_2 occurs when the input voltage is removed and a resetting signal is applied to the MEMORY. As in the case of the MEMORY circuit alone, simultaneous presentation of both inputs results in zero output. A resetting voltage applied at the time delay reset terminal immediately drops the voltage output to zero even though C_2 has not yet been discharged completely.

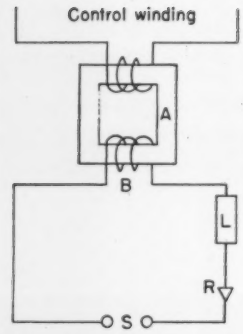


Fig. 11 — Simple magnetic-amplifier circuit.

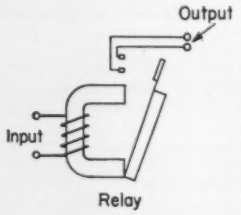


Fig. 12—Basic design of a simple electromechanical relay. Contacts can be normally open or normally closed.

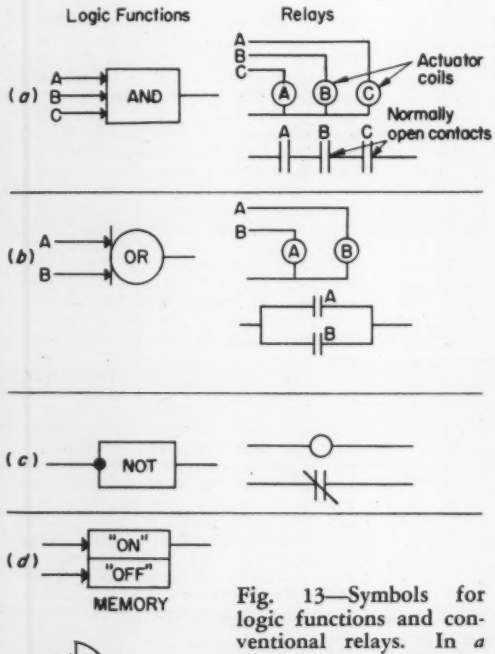


Fig. 13—Symbols for logic functions and conventional relays. In *a* (left) is a three-input AND logic function which performs same function as three spst relays with contacts connected in series, *a* (right). In *b* (left) is a two-input OR logic function; it compares with two spst relays with the two sets of contacts in parallel. Symbol for NOT logic function equals a relay with a normally closed contact, *c*. In *d* is an *on-off* MEMORY logic symbol and in *e* is a TIME DELAY symbol.

basically a controllable impedance inserted between a source of electric power and a load. The impedance is controlled by saturation of the magnetic core. Magnetic amplifiers differ from the saturable reactors mentioned previously in that they are self-saturating.

In the magnetic amplifier shown in Fig. 11, assume that the core is completely unsaturated. In the first half cycle, when power is applied, the core is unsaturated and the reactance of winding B is high; under these conditions only a small current flows in the load circuit. At the end of the first half cycle the core will be partially saturated by this small current. But if in the second half cycle, during which no current flows because of the rectifier in the power circuit, a control current is applied that unsaturates the core. By the time the next half cycle comes around again, no large load current can flow.

If no control current is applied, after a few cycles the core will become saturated by the small load current flowing through the high reactance of winding B. Once the core is saturated, the reactance of B will drop, and a large load current will flow in the circuit. Thus, with a small control current large amounts of power can be controlled in the load circuit. Commercial amplifier circuits naturally are more complicated than the simple one explained here, but the fundamental principles are the same.

A power gain of several million is possible with a magnetic amplifier with a resultant increased time delay. However, dc input signals smaller than 1 microwatt are difficult to handle with existing designs.

TRANSISTOR AND CAPACITOR AMPLIFIERS: In addition to its good characteristics as a switch, the transistor provides amplifying characteristics that can be applied in a manner similar to the magnetic amplifier. However, the transistor as well as the voltage-sensitive capacitor amplifier do not permit isolation of the input and output signals as does the magnetic amplifier.

THERMOCOUPLE AMPLIFIERS: Often, weak signals

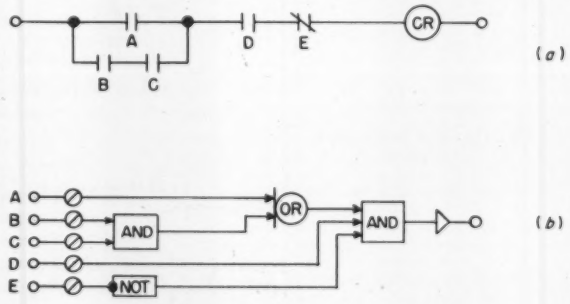


Fig. 14—Simple relay schematic diagram, *a*, and equivalent logic-function diagram, *b*.

can be additive, such as in a temperature-sensing system using a thermocouple. Here useful control voltage can be obtained by connecting a quantity of these thermocouples in a series, forming a thermopile.

Static Logic Devices Perform Relay Functions: One important field of pilot-control circuitry deals with switching and combining discrete electrical signals. On-off or switching type control has been accomplished for many years by magnetically operated switches or relays; today, electronic and static devices also perform this function, Table 1.

RELAY FUNCTIONS: In the case of the relay, all possible pilot-control schemes and conditions can be satisfied by switches or contacts that are either normally open or normally closed of either the momentary or maintained type. When the proper

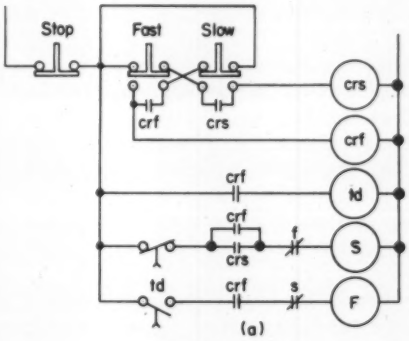


Fig. 15—Above—Typical two-speed pilot-control circuit for energizing the *slow* and *fast* motor windings using relays, *a*, and static logic functions, *b*. The bushbuttons are pilot devices.

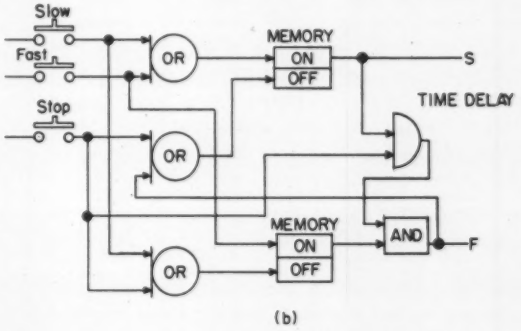
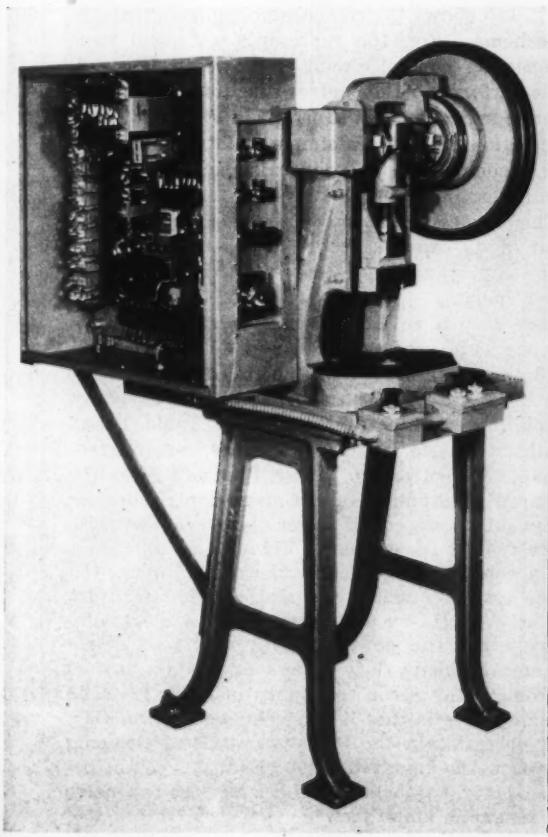
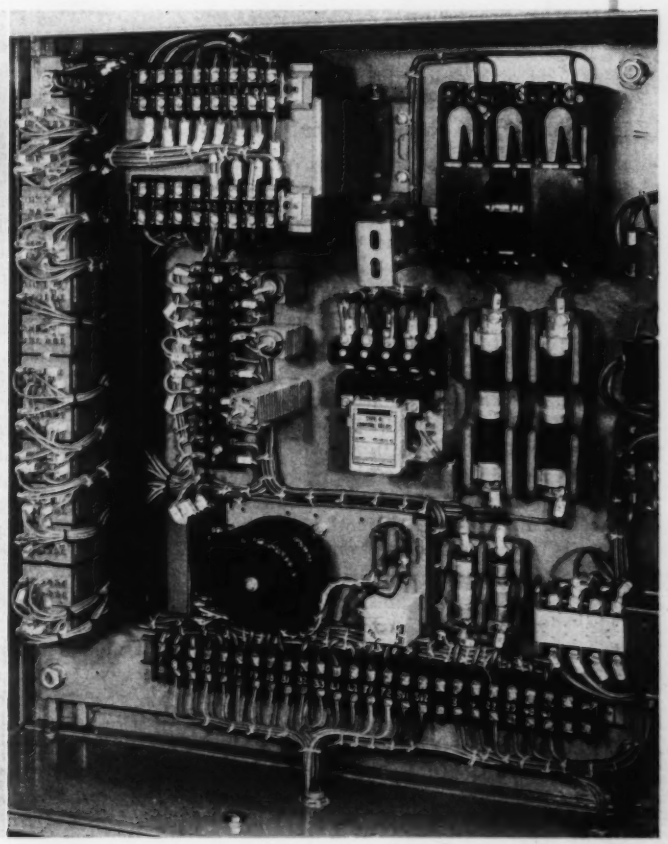


Fig. 16—Below—Static electrical control for the intelligence or signal processing in a punch-press application.





signal is applied these contacts, assume the opposite position. If the contacts are of the momentary type, they assume their original status when the signal is removed. If they are of the maintained type, it requires another signal or operation to reopen or reclose the contact. Characteristics may be designed into the devices so that a time delay occurs after the signal and before the contacts operate.

Fig. 12 illustrates the basic principle of a relay. The magnet mechanism, after a signal or input signal is imposed on the coil, moves to close or open the switches or contacts. The most commonly used relay employs a magnet circuit and from one to a dozen or more contacts which are either normally open or normally closed or in combination thereof. In this way, one input signal controls many contacts.

While this arrangement appears relatively simple, this is no longer the case in solving today's complex circuitry. As circuits become more involved, relays are called upon to perform more and more information processing and more and more contacts have to be added. Today some control schemes employ 12 and 16-pole relays, and two are even placed in parallel, so that one input signal will operate two relays or perhaps as many as 24 or more contacts. Also, for a given problem, several designers will end up with different quantities of relays and combinations to perform the same information processing.

TYPES OF LOGIC FUNCTIONS: In analyzing all combinations of contacts in pilot-control circuits, it is found that contact groupings or combinations occur in only four basic or logical arrangements.

Group 1 includes normally open contacts with one or more in series. In the computer art and the Cypak or static logic-control art, this combination is called an AND logic function. It implies that all contacts must be closed to produce an output or completed circuit. This is shown by the symbol in Fig. 13*a*. Such a logic function or device produces no output until all inputs are simultaneously available.

Group 2 includes normally open contacts with two or more in parallel. This is called an OR function, Fig. 13*b*. Logically any or all inputs produce an output.

Group 3 includes only one normally closed contact. This is a NOT function. Here when an input is not present, an output occurs, Fig. 13*c*.

Group 4 includes memory systems both unlimited (latched), Fig. 13*d*, and limited (time delay), Fig. 13*e*. The unlimited memory function, as the name suggests, delivers an output following an input until such time as a second input is fed into the system; the second input stops the output. Thus, the symbol in Fig. 13*d* is an *on-off* MEMORY function. Limited means that following an input signal a time delay occurs before an output is obtained. Thus, the memory system in Fig. 13*e* is simply a TIME DELAY function.

These logic functions are not new. Actually, they have been performed by relays for years. The AND function, for instance, has been accomplished by using three spst relays and placing relay contacts in series, Fig. 13*a*. The OR function is nothing more than two spst relays with the relay contacts in parallel, Fig. 13*b*. The NOT function has been accomplished by normally closed contacts, Fig. 13*c*, and the *on-off* MEMORY by the well-known latched-in relay. Logic functions can be accomplished with circuits employing electronic tubes, transistors and/or magnetic components.

Designing Logic Function Controls: The relay must be wired and purposely arranged to achieve a specific function, whereas the logic function mechanism requires no adjustment because it has been designed to do the specific job. This not only means that the process of design is different but also that manufacture and assembly are different. One of the important differences to date is that the logic element has a single ouput and can have a number of inputs, while the relay normally has only one input and a number of outputs. Naturally, there are advantages and disadvantages to both of these approaches. Logic functions adhere closely to the true fundamentals of control. Designs can be expressed and solved mathematically with Boolean algebra. Hence, designers will be able to solve more complex problems, and will also be able to simplify circuits as the state of the art progresses.

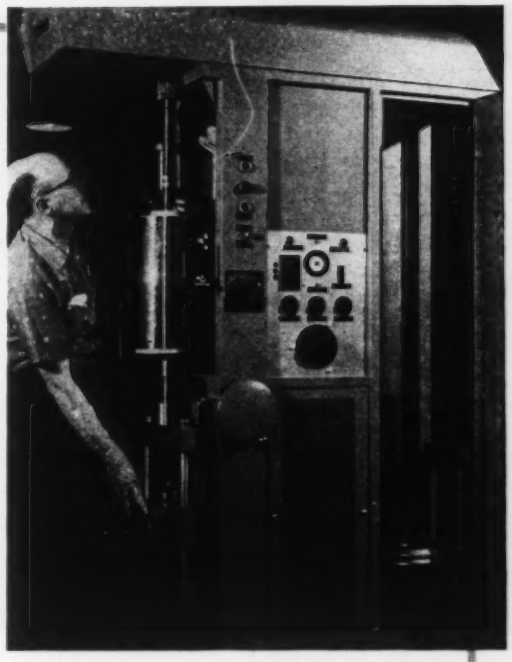
Fig 14*a* illustrates a control scheme involving series, parallel and normally closed contacts, whereas Fig. 14*b* shows the comparable logic control circuit scheme. Fig. 15*a* represents a typical two-speed starter control circuit employing relays. A circuit performing the control function using static magnetic logic elements is shown in Fig. 15*b*. These static logic elements are simple to interconnect because a common ground can exist between the input and output windings. The input circuits of all elements can be designed to operate from the output of all other elements. Also the output of any element can be used to drive from one to 20 other elements.

While such a variety of static electrical control elements have been designed and developed, Figs. 1, 2, 3 and 10, to make up complete control systems for a large number of applications, it is important to weigh the factors mentioned in Table 1 and combine those elements, whether they are electromechanical, electronic or static, that will make the best control. Applications of static control devices with pushbuttons, on-off power disconnect switches, and relays are illustrated in Figs. 4 and 16.

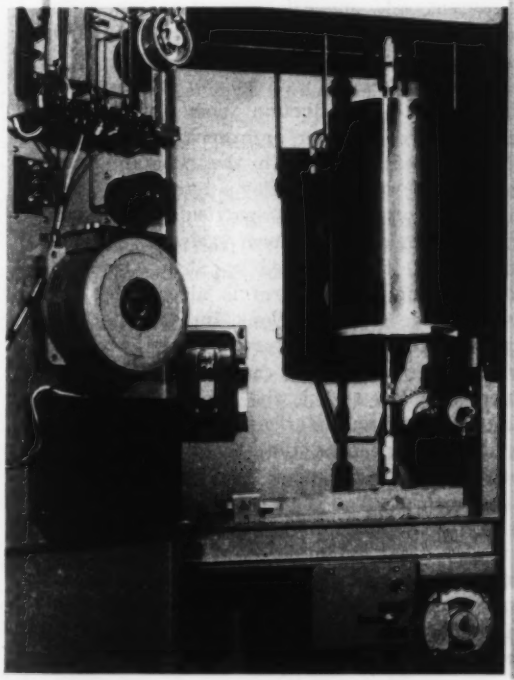
In a control design requiring considerable intelligence and processing, the static logic functions, such as provided by Cypak, may be the ideal solution whereas the power control may be electromechanical (heavy-duty relays or contactors) or electronic (thyratron or ignitron tubes). The reasoning here is that it is much easier to troubleshoot or maintain the few power-control elements than it is the involved pilot circuitry. Also, because of cost, contactors or tubes are less expensive than magnetic amplifiers.

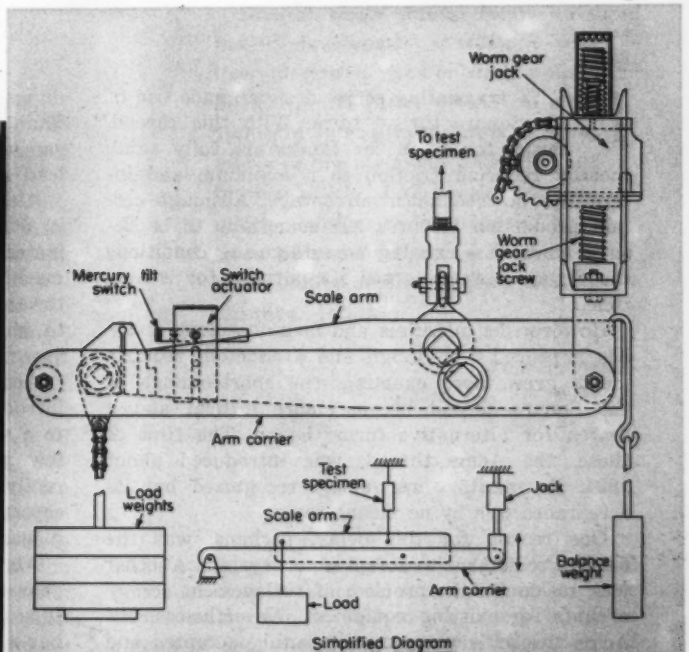
Moving Fulcrum Improves Creep Tester

USE of a wormgear jack in high-temperature creep-testing machines is said to make them the first such machines to apply a true axial load to the specimen under test. Basically the tester consists of a furnace which heats the test specimen to temperatures as high as 2200 F while loading the specimen as highly as 20,000 lb. The machine is a product of Arcweld Mfg. Co.; wormgear jacks are made by Duff-Norton Co.



True axial loading is maintained by lowering the fulcrum point of the scale-arm carrier to keep the scale arm very nearly level despite elongation of the test specimen. Only 0.00025-in. elongation of the test specimen is necessary to cause corrective leveling action to be automatically initiated. When the specimen elongates by 0.00025-in., a switch actuator mounted on the scale arm operates a switch which in turn closes a relay to start the motor driving the wormgear jack. When the jack has lowered the fulcrum point sufficiently to level the arm, the motor circuit is broken. Of necessity, the lowering must be done very gently to avoid any sudden movement or shock which could snap the specimen or, perhaps, introduce fatigue factors which would give inaccurate results. Characteristics of the jack used fulfill these requirements very satisfactorily.





CONTEMPORARY DESIGN

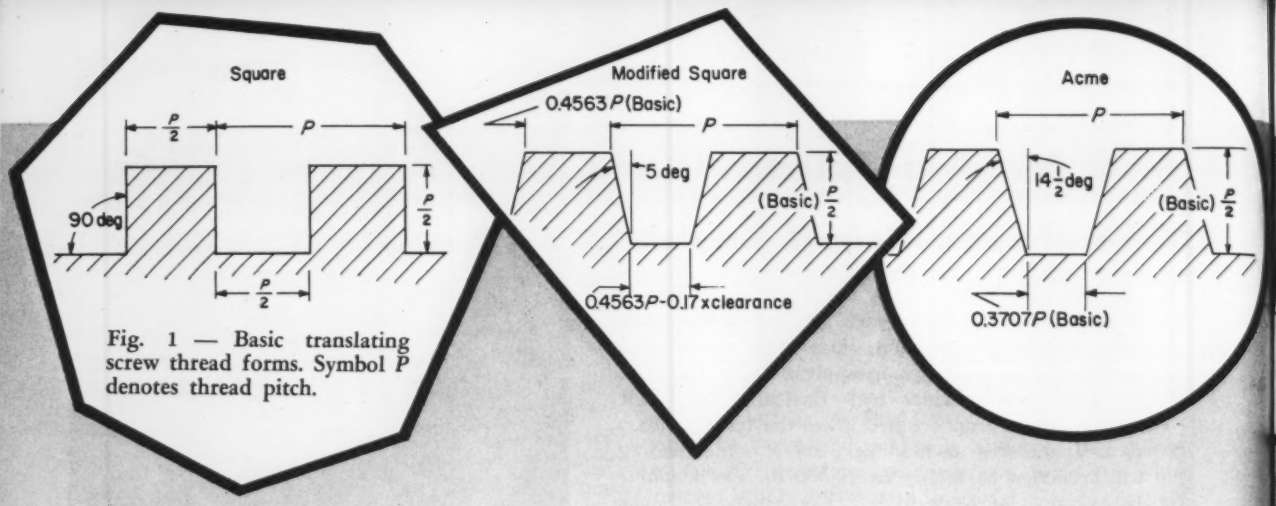


Fig. 1 — Basic translating screw thread forms. Symbol P denotes thread pitch.

Design Guide

Translating Screw Threads

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EARLY translating screw designs made use of the Square thread form. With this thread, thrust forces on the flanks are fully axial, thereby reducing friction to a minimum and increasing the mechanical advantage. Although certain production features left something to be desired, under the existing manufacturing conditions the Square thread served its purpose for a long time.

However, as materials and manufacturing methods improved and design and production requirements grew more exacting, the shortcomings of the Square thread became more critical and a search for alternative forms began. The first of these, the Acme thread, was introduced about 1894. Its merits were quickly recognized but its acceptance was by no means rapid.

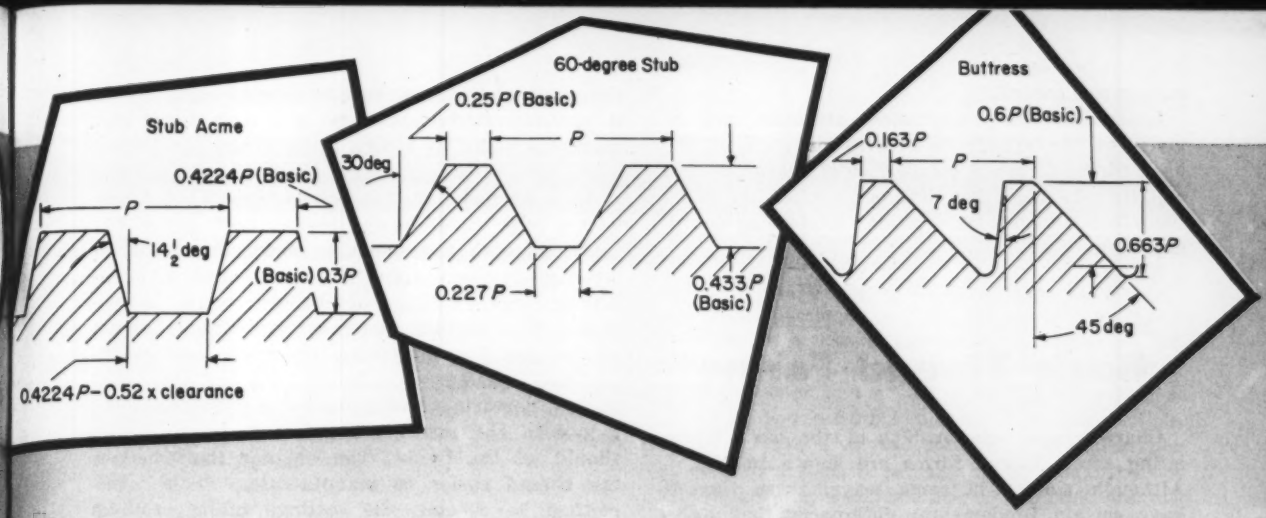
One reason for this delay, perhaps, was the natural reluctance to accept a new system. Another was, no doubt, the problem of replacement screws or nuts for existing equipment. Nevertheless, the Acme thread is now quite generally accepted and has found a wide range of application in power-screw drives. As compared to the Square thread, it offers certain advantages in both production and inspection. Moreover, there are other purely functional gains such as the possibility of pitch diameter compensation for lead error, increased flank contact, and smoother operation where the use of split nuts is involved as, for example, in lead screws.

Although the Acme thread was an improvement, it did not solve all production problems. With the increasing use of tougher or otherwise harder-to-machine materials, and with the constant trend toward greater accuracy, efforts have been made to improve upon the Acme, particularly with respect to finding a thread form easier to machine.

Around 1900 the modified or Stub Acme was introduced. This thread form is also well suited to a wide range of applications. In fact, there are few places where it cannot replace the Acme directly. However, as in the case of the Acme, acceptance was slow and it was not until 1952 that it was designated an American Standard.

About the same time that the Stub Acme appeared, the Modified Square thread came into use. It is easier to produce than the Square thread but has many of the same drawbacks and has not been used to any great extent.

During this period, the Sellers or, as it is known now, the American National thread form was modified in various ways to adapt it to translating service. The basic thread form, which has a true



Basic Forms
Production Considerations
Operating Characteristics
Selection Factors
Design Data

Rotary-to-linear conversion of motion or power can be accomplished in a number of ways. One of the most convenient and effective methods is that offered by the various translating or power screws. Adaptable to a wide range of power and service requirements, these units provide a simple but compact mechanical drive assembly.

Several screw thread forms have been developed specifically for transmission of power and motion. Basic characteristics of the different standard thread forms now in common use are reviewed and analyzed in this article. Ball-bearing screws, which involve certain special features of construction, were covered in an earlier article (*Machine Design*, October, 1955).

triangular shape with 30-degree flank angles, is the most common form used in fasteners. Of the modifications, the 60-Degree Stub thread discussed here is perhaps the most versatile.

Another standard translating form is the Buttress thread. Proposed in 1888, it antedates most of the others. Unlike the other forms, however, it was developed not to replace the Square thread but to fulfill a particular need. It is designed to exert thrust in only one direction. Thread shape is nonsymmetrical with one flank angle different than the adjacent one.

Basic Considerations: Although a wide range of operating characteristics is offered by these different thread forms, it is surprising how often the possibilities are overlooked in design. Frequently, screw threads are specified on the basis of standard or past practice without an evaluation of actual application requirements. In some cases, screws are designed to obtain a theoretical efficiency which, if realized, would exceed that necessary for the application.

For example, a positioning screw in a packaging machine or a tool-slide lead screw in a lathe may be designed with an Acme, Modified Square or other thread forms, having steep flank angles, when a high degree of efficiency is not needed and frictional drag is a minor factor. Likewise, these forms may be also utilized on clamp and vise screws of high helix angle where the amount of friction necessary for proper holding action could be better obtained with threads having greater flank angles. Then again the growing use of air and hydraulic power has changed the function of many screws from power delivery to that of ac-

tuation and control.

In the following discussion, attention will be given to the specific attributes of each of the basic thread forms. A comparison of characteristics will then be made for different application situations to illustrate considerations influencing design approach.

Basic Thread Forms

Characteristic relationships of the basic translating screw thread forms are shown in Fig. 1. Although similar in some ways, these threads have certain fundamental differences that influence selection and application.

Square Thread: Although not widely used now, the Square thread will be considered here for the sake of comparison. This thread is a true square form, having a depth and thickness of one half the pitch. Its zero-degree flank angle makes it the most efficient of the various forms, and also keeps friction to a minimum. It is, however, a difficult form to manufacture regardless of the production method. It doesn't lend itself to rolling. It imposes unfavorable "tool geometry" on any cutting tools. Also, if it is to be ground, it introduces the problem of dressing the square side of the grinding wheel, and the concurrent problem of maintaining lead accuracy.

Besides the difficulties in manufacture, numerous other shortcomings overbalance the advantages of this form. First, there is no chance for pitch diameter compensation for lead error. Secondly, flank contact is minimized. Contact with the mating thread on both flanks simultaneously is impossible. There can be little deviation from the zero-degree flank angle or interference will result. In addition, the alternative to looseness between the screw and nut in a radial direction is to have the bearing or contact with the mating part at either the crest or the root. This condition is highly undesirable.

There are many applications where any one of the previous features could be objectionable. Thus, it becomes readily apparent why this form has been superseded by others, in particular the Acme.

Acme Thread: Like the Square thread, the Acme has a basic depth equal to one half the pitch. However, here the similarity ends. Instead of a zero-degree flank angle, the Acme has a 14½-degree flank, making the included angle 29 degrees. The angular flank brings with it many advantages. By thickening the cross section at the root and, correspondingly, thinning the crest section, a much stronger thread is produced. Contact with the mating thread now occurs, as it should, at the flanks. The angular flank makes the thread easier to manufacture, whether the method be chasing, die cutting, milling, rolling or grinding.

This last feature is particularly important. These threads are translating threads and are used primarily for transmitting power or motion. Thus, smooth operation is essential. Surface finish of the flanks assumes paramount importance since friction must be kept to a minimum and wear life to a maximum. While theoretically the angular flank on the Acme thread creates a frictional component 3 per cent greater than that of the Square thread, this is invariably overcome by the reduction in frictional drag brought about by the improved surface finish on the flanks.

Stub Acme Thread: It is often difficult, even using the Acme form, to produce threads with the desired degree of surface finish. The material may be difficult to machine, the pitch may be extremely coarse, or factors peculiar to the particular design may make use of the relatively deep Acme thread form questionable. An alternative, to minimize costly roughing and finishing operations or grinding of the thread, is to substitute the Stud Acme form. It has a depth of only 0.3 times the pitch. Cross section at the root is nearly equal to that of the Acme. In addition, it has the advantages derived from the 14½-degree flank.

When machined, the Stub Acme form will usually have threads of high quality because the amount of stock removal necessary is greatly re-

Table 1—Comparison of Basic Translating Screw Thread Forms

Threads per inch	Basic depth				Total depth				Flank contact				Root cross-section			
	Acme	Stub Acme	60-deg	Stub	Acme	Stub Acme	60-deg	Stub	Acme	Stub Acme	60-deg	Stub	Acme	Stub Acme	60-deg	Stub
16	0.0313	0.0188	0.0271		0.0363	0.0238	0.0283		0.0322	0.0194	0.0312		0.0420	0.0387	0.0483	
14	0.0357	0.0214	0.0309		0.0407	0.0264	0.0324		0.0368	0.0221	0.0357		0.0475	0.0438	0.0552	
12	0.0417	0.0250	0.0361		0.0467	0.0300	0.0378		0.0435	0.0258	0.0416		0.0549	0.0507	0.0644	
10	0.0500	0.0300	0.0433		0.0600	0.0400	0.0453		0.0516	0.0309	0.0499		0.0681	0.0630	0.0773	
9	0.0556	0.0333	0.0481		0.0656	0.0433	0.0503		0.0574	0.0343	0.0555		0.0751	0.0694	0.0859	
8	0.0625	0.0375	0.0541		0.0725	0.0475	0.0566		0.0645	0.0387	0.0624		0.0838	0.0764	0.0966	
7	0.0714	0.0429	0.0619		0.0814	0.0529	0.0647		0.0737	0.0443	0.0714		0.0951	0.0878	0.1103	
6	0.0833	0.0500	0.0722		0.0933	0.0600	0.0755		0.0861	0.0517	0.0833		0.1100	0.1015	0.1289	
5	0.1000	0.0600	0.0866		0.1100	0.0700	0.0906		0.1032	0.0619	0.0999		0.1310	0.1207	0.1546	
4	0.1250	0.0750	0.1083		0.1350	0.0850	0.1133		0.1290	0.0775	0.1250		0.1625	0.1496	0.1933	

All dimensions are in inches.

duced. For example, an Acme with 10 threads per inch has a total depth of 0.060-in., while a Stub Acme of the same pitch has a total depth of 0.040-in. Work of the threading tool is thus reduced considerably for the Stub Acme form.

For this reason, the Stub Acme has been widely used in the aircraft industry. Many aircraft components are made from high-alloy steels and other nonferrous materials with tensile strengths in the upper ranges and with extremely low machinability factors. There have been instances where such parts were machined satisfactorily when the Stub Acme thread was used. These same screws had to be ground when the full-depth standard Acme thread was specified.

To meet requirements which are not wholly fulfilled by the Stub Acme form, there are two accepted alternative modifications. These are designated M1 and M2. The former is somewhat deeper than the Stub Acme and has a depth of 0.375 times the pitch, while the latter is shallower with a depth of 0.250 times the pitch.

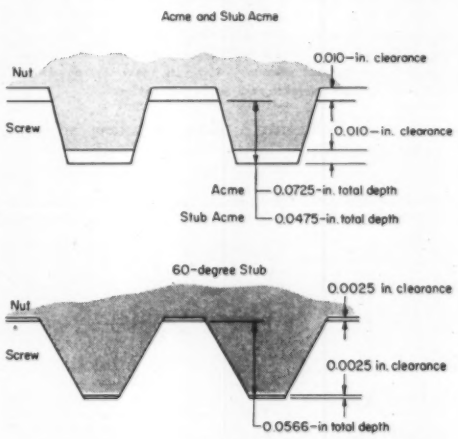
60-Degree Stub Thread: Slightly deeper than the Stub Acme, the 60-degree Stub form has a depth of 0.433 times the pitch. Flank angle is 30 degrees, making for still greater root cross section and flank contact than the Acme forms. The increased root cross section provides greater resistance to shear stresses.

The 30-degree flank has good machining characteristics particularly if the thread is a multiple-start design or has an extreme helix angle. Besides being easy to manufacture, the 60-degree Stub is much easier to measure than the other forms.

The 60-degree Stub facilitates engagement when split nuts are involved. Requiring less clearance at crest and root, it permits closer fits to be obtained, keeping backlash down. While it will inherently tend to give a higher degree of lead accuracy than any of the other translating threads, if lead error should occur there is more opportunity to compensate for it.

Use of the 60-degree Stub thread has generally been somewhat limited, except in certain valve applications. The primary reason for this is the fact that the 30-degree flank angle which contributes so much also has one detrimental feature. It reduces the efficiency of the thread. Although there are applications where the efficiency of the screw is of prime importance, there are also countless other jobs where the 60-degree Stub could effectively replace other forms with a substantial saving in production costs.

Modified Square Thread: Elements of the Modified Square form differ very little from the regular Square thread. Depth is the same, one half the pitch. Flank angle is 5 degrees, giving an included

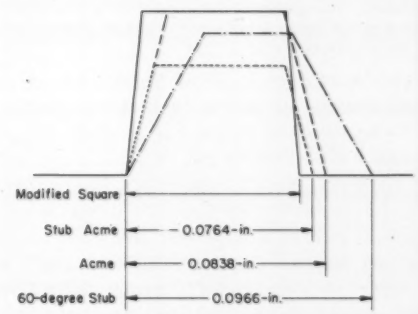


From Table 1, total depths for a screw design with 8 threads per in. are: Acme, 0.0725-in.; Stub Acme, 0.0475-in.; 60-degree Stub, 0.0566-in. Deepest is the Acme, followed by the 60-degree Stub. However, difference in total depths for the 60-degree Stub and Stub Acme is only 0.0091-in.

These differences in total depth are considerably less than for the basic depths. The variation stems from the allowed clearance values. For the Acme and Stub Acme forms, standard practice calls for an addition of 0.005 to 0.010-in. on the basic depth of thread of the screw and nut. In the example with 8 threads per in., this addition is 0.010-in.

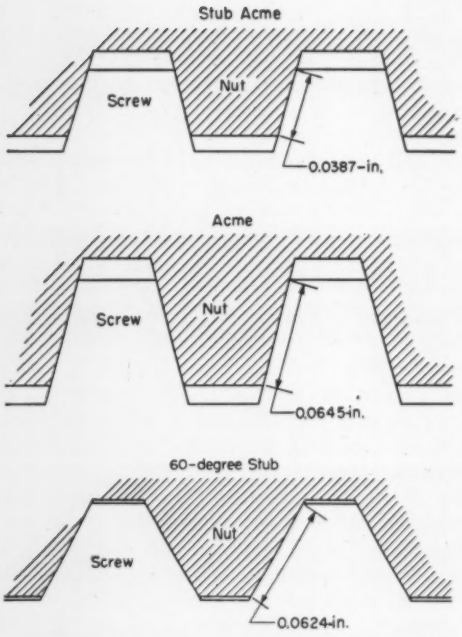
For the 60-degree Stub form, standard increase in basic depth for clearance is $0.02P$. In the design with 8 threads per in., this addition becomes 0.0025-in. The increase in basic depth required for the 60-degree Stub form is smaller than for the Acme forms because the 30-degree flank angle is conducive to closer fits.

Fig. 2—Comparison of thread depths and clearances of Acme, Stub Acme and 60-degree Stub forms for a screw design with 8 threads per in.



Width of thread cross section at the root determines to a great extent the axial thrust capacity of the thread. From Table 1, for a screw design with 8 threads per in., root cross section widths are: Acme, 0.0838-in.; Stub Acme, 0.0764-in.; 60-degree Stub, 0.0966-in. Greatest resistance to stripping action is provided by the 60-degree Stub, followed by the Acme form. As compared to the Stub Acme, which has the smallest width of cross section, the 60-degree Stub will average about 26 per cent greater width for the sizes listed in Table 1.

Fig. 3—Comparison of root cross sections of Acme, Stub Acme and 60-degree Stub forms for a screw design with 8 threads per in. Solid line indicates approximate profile of Modified Square Thread.



Flank contact, as defined here, is the actual distance along the thread flank at which contact occurs between screw and nut. This dimension has a direct influence on friction and wear characteristics of the screw assembly. Often, long nuts will be used in an attempt to prolong operating life of the screw assembly by increasing the wear surface. This solution would be logical if perfect contact could be assured along the entire length of the nut. However, this condition is rarely realized even on the most carefully manufactured parts.

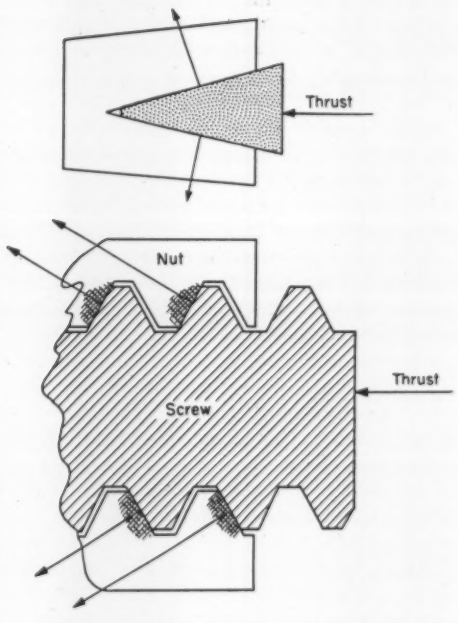
From Table 1, based on an 8 threads per in. design, flank contact is: Acme, 0.0645-in.; Stub Acme, 0.0387-in.; 60-degree Stub, 0.0624-in. Greatest contact length is provided by the Acme followed closely by the 60-degree Stub. For the Stub Acme, flank contact is 0.023-in. less than that of the 60-degree Stub. For the Acme and 60-degree Stub, this difference becomes 0.002-in. On a relatively coarse thread, say 4 threads per in., flank contact of the Acme is still only 0.004-in. greater than for the 60-degree Stub.

Fig. 4—Comparison of flank contact dimensions of Acme, Stub Acme, and 60-degree Stub forms for a screw design with 8 threads per in.

angle of 10 degrees. This small flank angle overcomes some of the manufacturing difficulties of the zero degree flank, and in turn, only slightly decreases the overall efficiency of the screw.

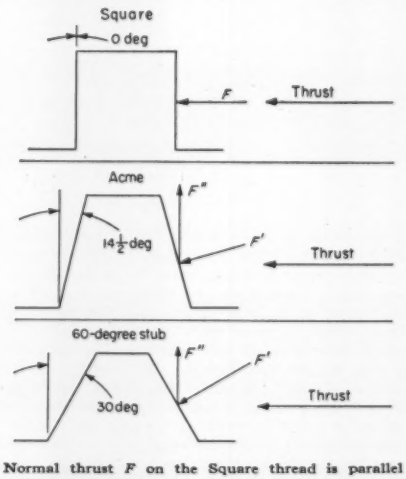
However, the Modified Square form is still so similar to the standard Square form and shares so many of the same drawbacks that it has never been very widely used. A useful application for this thread form is in light tubular parts, as exemplified by a shotgun barrel, where the low ratio of radial to axial thrust is highly desirable.

Buttress Thread: While the Buttress thread is not strictly a translating form, it merits consideration because of its borderline nature. There have been as many versions of this form as there have been applications. An American Standard



As thrust is applied to the screw, it tends to wedge or split apart the nut. This bursting or frictional force increases directly as normal pressure and is proportional to the secant of the flank angle. This increase, over the Square thread, is on the order of 15 per cent for the 60-degree Stub form and 3 per cent for the Acme form. The Square thread with its zero-degree flank angle, of course, creates no wedging action.

Fig. 5—Wedging action in screw and nut assemblies under thrust load.



Normal thrust F on the Square thread is parallel to the screw axis and perpendicular to the flank. For the Acme form this thrust becomes $F' = F \sec 14\frac{1}{2}$ degrees. Here, the radial or frictional component F'' produces a wedging action. Likewise, on the 60-degree Stub thread the thrust becomes $F' = F \sec 30$ degrees, and bursting or frictional component F'' is correspondingly increased.

Fig. 6—Effect of flank angle on friction forces developed by translating screw threads.

for this form was finally established in 1953.

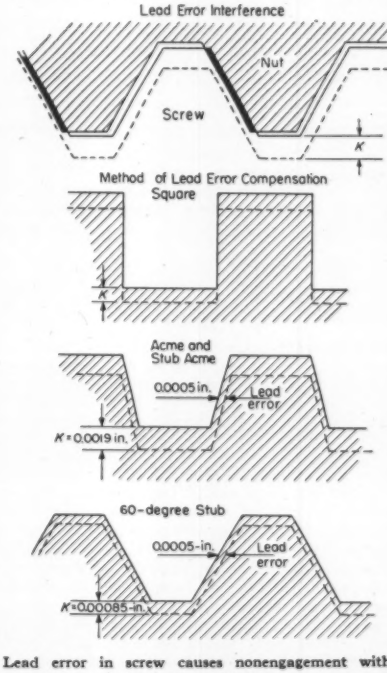
Depth of the Buttress is 0.6627 times the pitch. Leading, or pressure flank, has a 7-degree angle; trailing flank angle is 45 degrees. Crests are 0.163 times the pitch in width, and the roots have a radius of 0.071 times the pitch, tangent to both flanks.

The Buttress thread is difficult to manufacture and measure. This property stems chiefly from its asymmetrical form, which makes both uniform flank finish and accurate lead hard to obtain. This asymmetry also affects the gaging. Thread measuring wires, for example, can never contact both flanks at the pitch line simultaneously. Therefore, a compromise must be effected.

In addition, the less important 45-degree trailing flank, from a functional standpoint, has far greater influence on pitch diameter measurement than does the 7-degree pressure, or working, flank.

The Buttress thread is, nevertheless, an ideal form for certain applications, notably those requiring exceptionally high thrust in one direction only. It is particularly well suited for clamp screws, breech blocks in large guns, aircraft propeller hubs, screws for actuating adjustable wrenches, optical and ordnance parts on thin-wall material and parts subject to extreme impact, such as rock bits and drill rods.

As adopted, the Buttress form presents a well-conceived design which should be adhered to as much as possible. The steep 7-degree pressure flank reduces friction and, at the same time, increases the mechanical advantage. The long 45-degree slope of the trailing flank complements the pressure flank to produce a sizable root shear section which is substantially reinforced by the root radius.



Lead error in screw causes nonengagement with nut due to interference shown by shaded area in top sketch. Reduction of pitch diameter by a distance $2K$ compensates for this error. This reduction produces the screw form shown dotted to permit engagement with nut.

For the Square thread, reduction of pitch diameter will not change the axial position of the flank. Thus, compensation of lead error by the foregoing method is not possible. On the Acme and Stub Acme forms, compensation can be provided by reducing the pitch diameter $2K = 0.0038$-in. for each 0.001-in. of lead error. For the same lead error, the 60-degree Stub requires a pitch diameter adjustment of $2K = 0.0017$-in.

For convenience, pitch diameter change has been shown in these drawings as reflected only on the minor diameter.

Fig. 7—Analysis of lead error interference in translating screws and how it can be compensated in basic thread forms.

Comparison of Thread Characteristics

Basic thread forms discussed in the foregoing section offer a range of design and operating characteristics to suit different application requirements. These characteristics will now be analyzed and compared in detail for different standard thread forms. Comparisons will be confined, in general, to those threads which have to the greatest extent supplanted the Square form—the Acme, Stub Acme and 60-degree Stub. The modified Square thread will be omitted because its use is relatively limited. Also, the Buttress thread will not be considered because of its special-purpose nature.

Thread Dimensions: Comparative dimensional data for the Acme, Stub Acme and 60-degree Stub are given in Table 1. Thread depths of these three forms are compared in Fig. 2. Similar comparisons for root cross section and flank contact are given in Figs. 3 and 4, respectively.

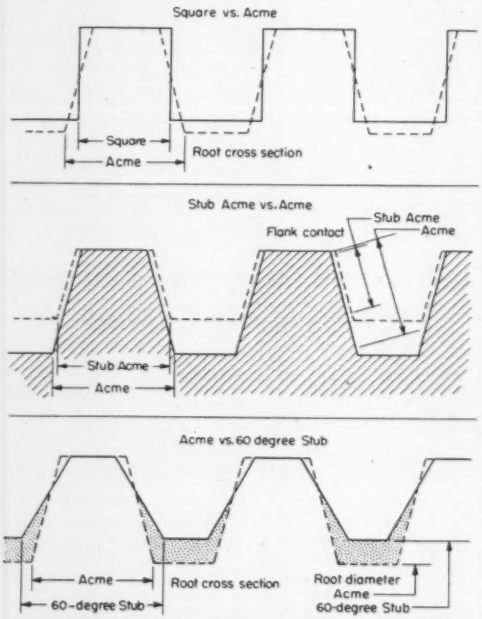
Friction and Efficiency: There are many factors which influence the overall efficiency of a translating screw. Not the least of these is the shape of the thread. It has a direct bearing on the pressure exerted on the thread, and at the same time on the frictional component produced. This relationship is perhaps best explained by Fig. 5, where the similarity between a thread and a common wedge is pictured.

An analysis of thread forces is shown in Fig. 6. As can be seen, the Square thread has theoretically the greatest efficiency. In practice, however, this apparent advantage is tempered by other considerations such as surface finish, helix angle, and load distribution, which make use of one of the other thread forms desirable.

While frictional drag is slight and often overlooked, it should be reckoned with in calculating screws which are to be heavily loaded. Also, the percentages given in Fig. 5 for increase of fric-

tional force presuppose equal flank contact in all cases. Since flank contact usually increases whenever the Square thread is replaced by the other forms, this consideration too will add to the friction factor. Both factors should be considered when loading is involved.

Pitch Diameter Compensation for Lead Error:



If a Square thread is employed for the screw design, rough thread surfaces will probably result because of difficulties in machining the thread form as well as the material. For the same thread pitch and diameter, machining conditions would be improved if an Acme thread is used. This improvement is due to the angular flank, even though the Acme thread is slightly deeper. In addition, flank contact with the mating nut will be greater for the Acme and the root cross section will be increased about 1/3. However, root diameter will be reduced by 0.020-in.

Further improvement in "machinability" is offered by the Stub Acme form with its shallower thread. However, as compared to the Acme form, this thread will have a small root cross-section and flank contact will be substantially less, about ½. For some applications, the reduction in stripping strength might be undesirable.

If a 60-degree Stub thread is used, the increased flank angle would again act to improve machining conditions. In addition, as compared to the Acme forms, root cross-section will be greater. Flank contact will be less than the Acme but greater than the Stub Acme.

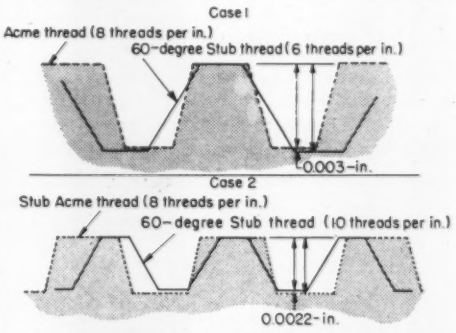
The large flank angle of the 60-degree Stub is also important from other standpoints. As compared to the Acme form, the 60-degree Stub will provide a larger root diameter. Where torsional deflection of the screw is a problem, this increase in root diameter acts to reduce the tendency to twist under load. Additionally, when long screws are mounted horizontally, there is always the possibility of sag. Even when slight, this condition can result in seizing at the flank surfaces. With a large flank angle, this action will be much less serious. At the same time, however, the large flank angle acts to increase the friction at the flank surface.

Fig. 8 — Comparison of characteristics of basic thread forms for application on a screw design with 8 threads per in. to be machined from a "tough" alloy.

Besides the elements just discussed, there is another less tangible but quite important factor to be considered in screw design. This is the possibility of pitch diameter compensation for lead error. By their very nature, some of these thread forms tend to engender lead error. This condition is primarily due to steep flank angles which resist the tool generating the thread. This resistance is naturally more pronounced on the Acme or Stub Acme forms than on the 60-degree Stub.

Many applications require extremely long screws, introducing the possibility of torsional deflection. Often a certain amount of this deflection is retained, creating lead inaccuracy even though the screw was originally quite precise. Regardless of the cause, when lead error does occur, preventing proper engagement with the nut, it is possible to make correction by reducing the pitch diameter. This adjustment is possible on any thread except the Square thread form, as illustrated in Fig. 7.

No correction can be effected on the Square thread because pitch diameter change does not affect the flanks in a lateral direction. But the other threads are subject to correction. However, for the same amount of lead error, it can be seen that it takes over twice as much pitch diameter reduction for correction of either the Acme or the Stub Acme forms as it does for the 60-degree Stub.


Case 1
Acme thread (8 threads per in.)
60-degree Stub thread (6 threads per in.)
0.003-in.
Case 2
Stub Acme thread (8 threads per in.)
60-degree Stub thread (10 threads per in.)
0.0022-in.

Two cases will be considered, substituting a 60-degree Stub form for (1) an Acme thread and (2) a Stub Acme thread. Initial screw design in each case will be assumed to have 8 threads per in.

In the first example, total depth for an Acme thread with 8 threads per in. is, from Table 1, 0.0725-in. Nearest matching dimension is provided by the 60-degree Stub form with 6 threads per in. and total depth of 0.0755-in. This depth should be close enough to fulfill root diameter requirements and still stay within tolerance. As compared to the Acme thread form, the 60-degree Stub thread provides a wider root cross section and greater flank contact. However, it has been necessary to increase thread pitch to make the substitution. Although metal removal will be greater for the 60-degree Stub, ease of machining the larger flank angle may compensate for this factor.

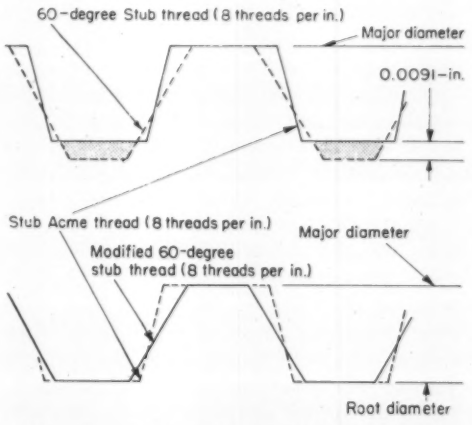
For the second substitution example, a 60-degree Stub form with 10 threads per in. could be used to replace the 8-thread Stub Acme. From Table 1, difference in total depths of the two threads is about 0.002-in. Root cross sections would be about the same width for both forms although flank contact for the 60-degree Stub would be greater. Also, in this case it has been necessary to reduce thread pitch to make the substitution.

Fig. 9—Effect of substitution of thread forms on screw design where root diameter is a critical dimension.

Thread Application: Characteristics of the various thread forms often offer several alternative possibilities in actual practice. Factors influencing design approach for different requirements are analyzed in the representative application examples shown in Figs. 8, 9, 10 and 11.

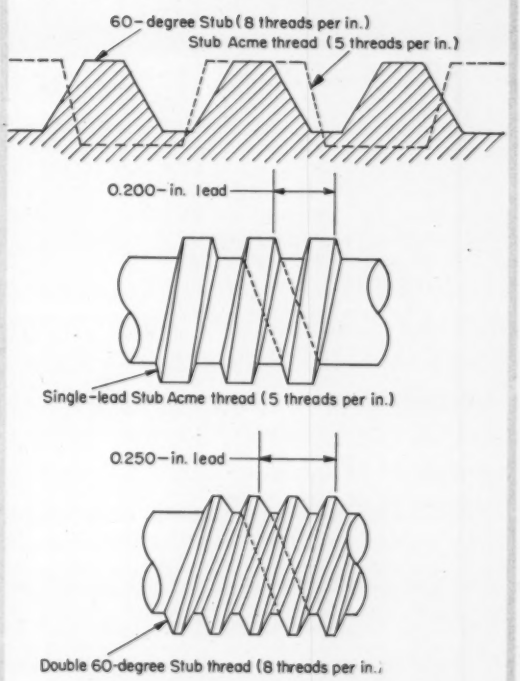
The application example covered in Fig. 11 emphasizes the fact that in the design of translating screws, multiple threads should be considered for their particular attributes. They are generally more difficult to machine. Care must be taken in design to see that overhauling will not occur, due to the helix angle being greater than the angle of repose. The mechanical advantage will be lower, but the efficiency will be greater. Despite these limitations, there are many applications where the advantages of using a multiple-start thread far outweigh the drawbacks.

Design Outlook: Although only a few representative conditions have been analyzed, the foregoing examples illustrate some typical factors to be considered in screw design. Attributes of a particular thread form that will be beneficial in one situation may work adversely in another. Evaluation of the favorable characteristics as well as of the limitations of each of these threads offers a practical guide to selection of the most suitable form for a particular application.



For a screw design with 8 threads per in., substitution of a 60-degree Stub form for a Stub Acme thread will result in a reduction of root diameter because of the greater total depth of the 60-degree thread for that pitch. This decrease, which is 0.018-in., will still permit the thread to fall within Class 2 limits for either general purpose or centralizing fits. However, it will not meet Class 3 and 4 tolerance requirements. Moreover, the root diameter reduction may be undesirable for other reasons. One approach to the problem is a modified 60-degree Stub form in which depth has been decreased to correspond to that of the Stub Acme thread. In practice, this correction can be readily accomplished by modifying standard threading tools. As compared to the Stub Acme form, the modified thread has equal pitch and total depth but flank contact and root cross section are greater.

Fig. 10 — Modification of 60-degree Stub thread for substitution with Stub Acme form where root diameter is critical.


60-degree Stub (8 threads per in.)
Stub Acme thread (5 threads per in.)
0.200-in. lead
Single-lead Stub Acme thread (5 threads per in.)
0.250-in. lead
Double 60-degree Stub thread (8 threads per in.)

For certain translating screw applications maximum wear surface becomes a primary requirement. This condition is usually the case where the screw function is to provide precision control of motion. Thread shear strength and resistance to torsional stress are usually secondary considerations in such applications.

As an example, consider a traversing screw design for a business machine or gunsighting mechanism. In the initial design, a Stub Acme form with 5 threads per in. has been employed to meet space limitations. If a 60-degree Stub thread is substituted for the Stub Acme form, equal flank contact should be maintained since wear surface is critical. From Table 1, the 60-degree Stub form with 8 threads per in. provides the closest match. Root cross section is reduced with this thread but root diameter is increased.

Screws of the foregoing type will often be made of high-alloy or corrosion-resistant material. In that event, ease of manufacture may be an important factor. The finer pitch, shallower thread, increased flank angle and reduced helix angle of the 60-degree Stub form would offer advantages in machining. However, frictional resistance of the thread would be greater.

Another point that may be important is the speed of advance. The 60-degree Stub form with 8 threads per in. would provide a "slower" thread than the Stub Acme design with 5 threads per in. If a slower advance is undesirable, the condition could be rectified to some extent by using a double instead of a single-lead thread.

For the Stub Acme thread, the lead of advance per revolution is equal to the pitch which is 0.200-in. If a double 60-degree Stub thread is used, the lead or advance is doubled to 0.250-in. This value represents an increase over the Stub Acme form, but if speed of advance is important this increase will usually be welcome. Change in helix angle for the double thread would not appreciably affect machining characteristics. On a $\frac{5}{8}$-in. diameter screw, the helix angle of double 60-degree Stub thread would be 7 degrees 56 min, only 1 degree 20 min greater than that of the single-lead Stub Acme thread. On a 1-in. diameter screw, the difference would be less than 1 degree.

Fig. 11—Analysis of substitution of 60-degree Stub thread for Stub Acme form where amount of wear surface is critical.

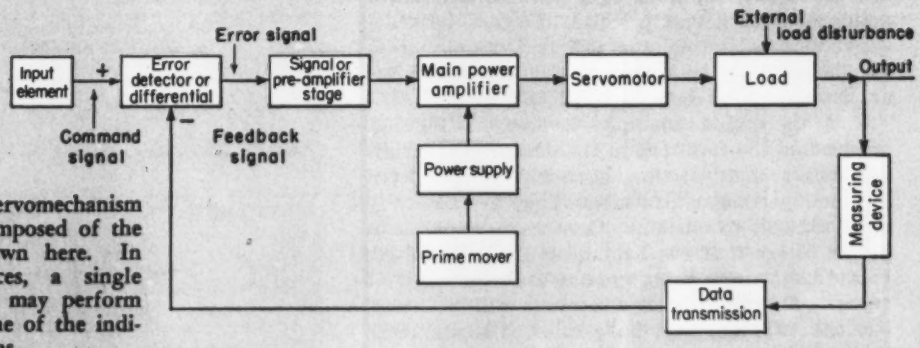


Fig. 1—A servomechanism is usually composed of the elements shown here. In some instances, a single physical unit may perform more than one of the indicated functions.

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Hydraulic Servo

. . . their effect

BASIC hydraulic servo components will be discussed in this article. These components will be considered only in so far as they affect system performance, and not from the standpoint of mechanical design. In hydraulic servos there are a number of ancillary components which do not normally affect the performance of the system from the control point of view. These elements, such as filters, accumulators, nonreturn valves and priming pumps, will in general be omitted from the discussion.

A servomechanism is classified according to its power drive. This comprises the main amplifier, the power source and the servomotor. It is in fact the *muscle* of the system. Thus in a hydraulic servo the power drive consists of the appropriate hydraulic machinery, for example: a pump, selector and motor. In an electrical servo the power drive might consist of a Ward-Leonard system. Although this article is concerned only with hydraulic servos, the underlying principles are the same for servos in general.

Closed-loop control systems include a number of basic elements in the forward loop and the feedback path, Fig. 1. Each of the basic elements may actually be several separate physical components. Sometimes one physical component performs functions of two or more of the basic elements.

Input Element: Command signal to the system is supplied by the input element. In most hydraulic servos the command signal is either a displacement or a voltage. This latter implies the use of electrical components in the low-power side.

In some instances, a hydraulic servo may be only a part of a more complex control system, Fig. 2. In such cases the input element is the preceding element in the control sequence.

Error Detectors: Function of the error detector in a servo is to observe any difference between the output and the input and to produce a signal, the error signal, proportional to this difference. In most cases this is achieved by subtracting from the command signal a measure of the output obtained from the feedback elements. This feedback signal must be of the same physical nature as the command signal. For instance, if the command signal is a voltage and the output is a displacement, then the feedback measuring device must convert the output displacement into a proportional voltage. When both input and output signals are voltages, they can be subtracted directly, Fig. 3*a*, if impedances are suitably matched.

In many cases some form of differential is needed to subtract the feedback signal from the command signal. For instance, if both are displacements, either a lever differential for straight-line motion, or a gear differential for rotational motion can be used, Fig. 3*b*. Accuracy of these systems

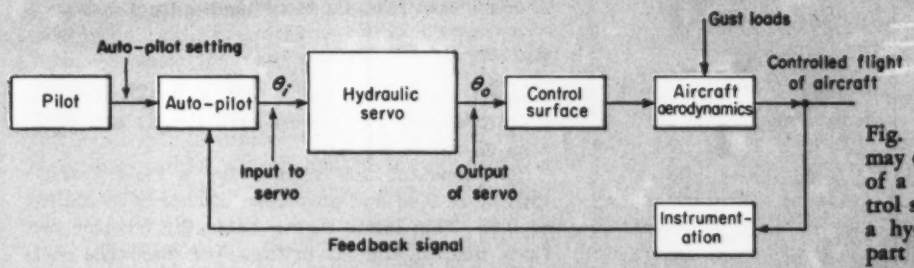


Fig. 2—A servomechanism may often be only a portion of a more complicated control system. In this instance, a hydraulic servo is but a part of a complete aircraft autopilot control system. The servo is the power amplifying link between the autopilot and the control surfaces.

Components—1

on system performance

- **Input Elements**
- **Error Detectors**
- **Valve Amplifiers**
- **Power Supplies**

is limited by backlash in the joints and bearings.

Other differentials can be devised for subtracting other kinds of quantities—for example, pressures and forces, Fig. 4. By introducing springs, Fig. 5, displacement error signals can be produced. Disadvantage is the lack of accuracy due to the spring characteristics and friction, particularly if the error signal has to overcome any appreciable load. Although these devices are, therefore, not very satisfactory for the main feedback loop, they can be used for local feedback loops which are sometimes put around elements within the main loop to improve their characteristics.

Sometimes, feedback is purely virtual, as in speed governors, for example. In this case no differential is needed. Here, the governor is called an error-sensing device since it senses rather than measures the difference between the output and the input.

In some instances functions of output measuring, data transmission and error detecting are carried out by single element.

Control Valve Amplifiers: Simplest type of power amplifier used in hydraulic servos is the control valve. Most common is the slide-valve amplifier, Fig. 6. Control valves are essentially variable orifices which offer a controllable resistance to the flow from a source of power. Normally each valve is a sharp-edged orifice and the flow through it is given by Bernouilli's equation, with an appro-

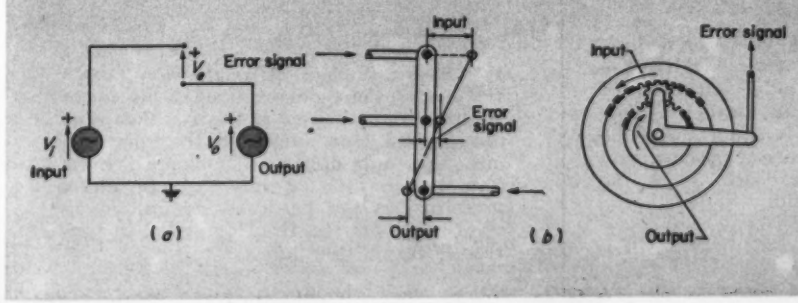


Fig. 3—Lever or gear differentials are used in servos to subtract the feedback signal from the input or command signal when these signals are mechanical quantities, *b*. Accuracy of such devices is limited by backlash or play in joints and bearings. Higher accuracy is obtainable if both signals are voltages since they subtract directly, *a*.

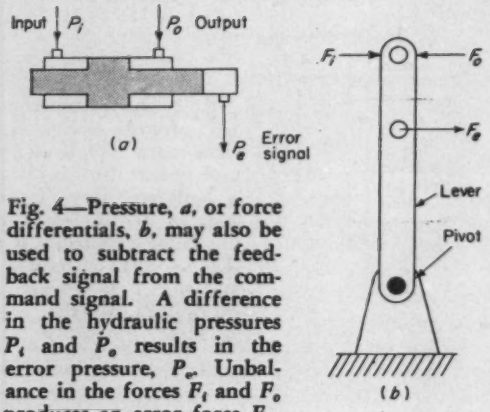


Fig. 4—Pressure, *a*, or force differentials, *b*, may also be used to subtract the feedback signal from the command signal. A difference in the hydraulic pressures P_i and P_o results in the error pressure, P_e. Unbalance in the forces F_i and F_o produces an error force F_e.

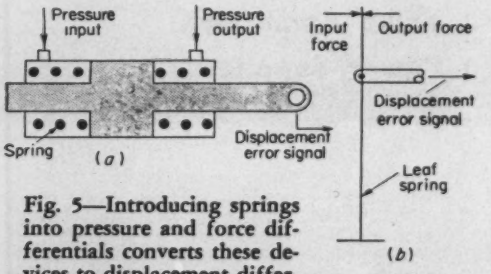


Fig. 5—Introducing springs into pressure and force differentials converts these devices to displacement differentials. Spring characteristics and friction introduce inaccuracies, but these devices are, nevertheless, useful in local feedback loops.

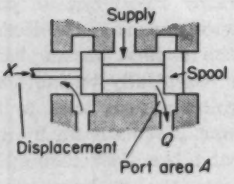


Fig. 6—Simplest type of power amplifier used in hydraulic servos is the control valve. Most common type is the slide valve shown here.

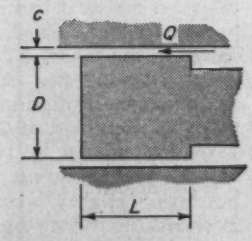


Fig. 7—When hydraulic flow is through a parallel channel of small clearance, flow *Q* is a function of the dimensions shown and the viscosity of the fluid.

priate correction for energy dissipated as heat. A convenient formula to remember for the flow is

$$Q = 100\ A\ \sqrt{P} \qquad (1)$$

where Q = flow through orifice, cu in. per sec; P = pressure drop across orifice, psi; and A = area of orifice, sq in.

The constant 100 applies for a fluid specific gravity of 0.89 and an orifice discharge coefficient of 0.65. This latter figure holds for circular orifices, but for annular orifices, the discharge coefficient is more like 0.8. In this case a figure of 130 instead of 100 should be used.

Sometimes valve ports are viscous resistances. Here the flow passes through a parallel channel of small clearance. For an annular flow path, Fig. 7, the flow is given by

$$Q = \left(\frac{\pi D c^3}{174{,}000\ \nu L} \right) P \qquad (2)$$

where D = diameter of annulus, in.; L = length of land, in.; c = clearance, in.; and ν = dynamic viscosity, poises.

Nomenclature

A = Area of orifice, sq in.
c = Valve spool radial clearance, in.
D = Diameter of annulus, in.
$f(x)$ = Function of x
H_p = Power delivered by pump, lb-in. per sec
K = Constant
L = Length of valve spool land, in.
N = Rotational speed, rpm
P = Pressure, psi
Q = Flow through orifice, cu in. per sec
T = Torque, lb-in.
V = Volumetric displacement, cu in.
x = Displacement, in.
η = Efficiency
ν = Dynamic viscosity, poises

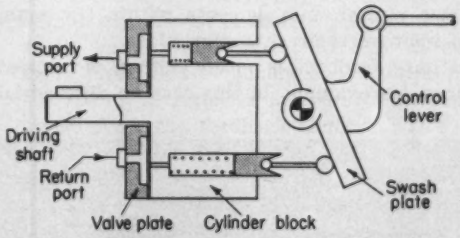


Fig. 8—Swash-plate or axial-piston pumps are one of the types of fixed-displacement pumps commonly used in servos. Pumps of this general type are called fixed-displacement or simply displacement pumps because flow rate is affected very little by outlet pressure. In this particular design, swash-plate angle may be fixed or varied to provide different flow rates.

In control valves, viscous resistances are varied by altering length, L. Viscous resistances are also used in hydraulic networks as constant resistances. However, since they are sensitive to temperature variation, some form of compensation must be provided.

Viscous orifice control valves, sometimes called throttling valves, are of limited use in sensitive servos because in general only small flow rates can be handled.

In the normal type of variable-orifice valve, the controlling member—the valve spool, Fig. 6—is displaced according to some measure of the error signal. The exposed orifice area will depend on the valve displacement, x. The flow is given by an equation of the form,

$$Q = f(x)\ \sqrt{P} \qquad (3)$$

Since the force required to operate the valve has only to overcome friction and hydrodynamic forces, considerable power amplification can be achieved. Power is monitored from a constant pressure supply in most cases.

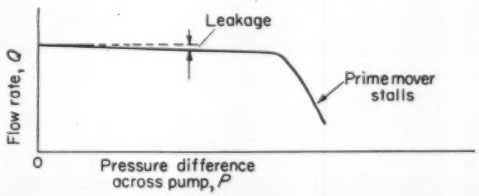


Fig. 9—As pressure differential varies across a fixed-displacement pump driven at constant rpm, the flow rate Q is substantially constant. There is a slight reduction in flow because of increased leakage at higher pressures. If pressure becomes sufficiently high, the prime mover will not maintain speed and will stall.

Power Supplies: Power is supplied in the form of fluid under pressure from hydraulic pumps. In hydraulic servo applications, pumps are almost invariably displacement pumps and not dynamic pumps. The flow delivered by displacement pumps depends only on the capacity of the pump and on the speed of the prime mover which drives it. In the case of dynamic pumps, typified by centrifugal pumps, flow is so affected by output pressure, temperature and so on that these pumps are not really suitable for control applications.

Displacement pumps are, for example, radial-piston and swash-plate or axial-piston pumps, Fig. 8, gear pumps or vane pumps. They deliver a constant volume V_p per revolution of the driving shaft. Therefore, if they are driven at a speed of N revolutions per minute, the flow delivered is, neglecting for the moment the small losses due to leakage and compressibility,

$$Q = \frac{NV_p}{60} \qquad (4)$$

where Q is the flow rate in cu in. per sec and V_p is pump displacement in cu in. per rev.

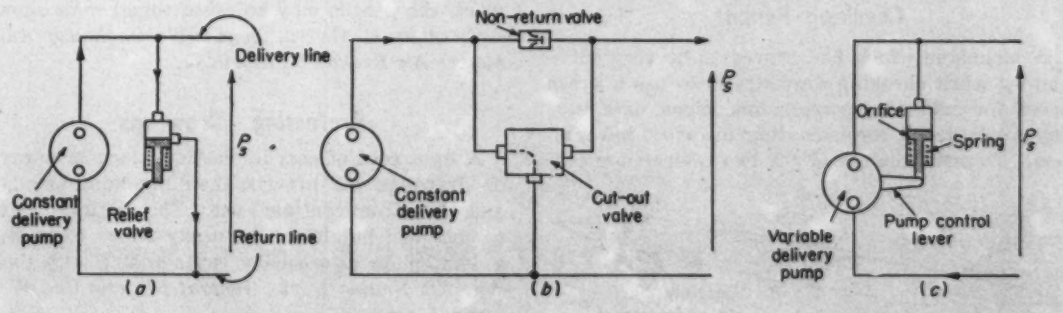
Power supplied by the prime mover is $2\pi NT/60$ lb-in. per sec. Power delivered by the pump is QP lb-in. per sec, where P is the excess of pump delivery pressure over reservoir pressure. Then, if η_p is the efficiency of the pump,

$$H_p = QP = \eta_p \left(\frac{2\pi NT}{60} \right) \qquad (5)$$

where H_p is the power delivered by the pump in lb-in./sec.

Pressure delivered by the pump depends on the resistance met by the constant fluid flow. In prac-

Fig. 10—To achieve constant-pressure supply from a hydraulic pump, a relief valve is placed in the pump delivery line, *a*. However, the pump must then deliver flow at full system pressure even though no power is required by the circuit. This drawback can be overcome by using a cut-out valve to open an idling circuit when there is no system demand, *b*, or by using a variable delivery pump controlled by system pressure, *c*, to automatically increase or decrease output to maintain constant pressure.



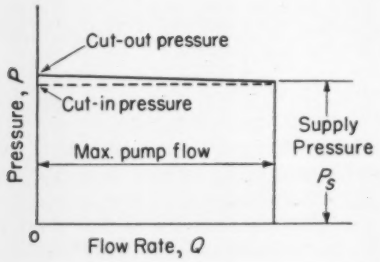


Fig. 11—Flow-pressure characteristic of systems shown in Fig. 10 is nearly constant from zero to full pump flow rate.

tice the flow is not strictly constant but is slightly influenced by P, because of leakage. Leakage is roughly proportional to P and causes the pump flow-pressure curve to vary, Fig. 9. At high pressures the leakage is of the order of 5 per cent. Maximum available pressure is limited by stall torque of the prime mover, Fig. 9. By combining Equations 4 and 5 an expression for the pressure is obtained:

$$P = \frac{2\pi\eta_p T}{V_p} \qquad (6)$$

Thus, apart from leakage and compressibility effects, a displacement pump is essentially a constant-flow generator. However, with valve-controlled servos a constant pressure supply is required. This can be achieved by means of a pressure-relief valve in the pump delivery line, Fig. 10*a*. But this system has a drawback in that even when no power is demanded by the servo, the pump delivers flow at full system pressure. This means unnecessary wear and tear on the pump. This can be overcome by using a pressure-operated cutout valve to open an unloaded idling circuit when there is no demand from the system, Fig. 10*b*. An alternative scheme is a variable delivery pump controlled by system pressure, Fig. 10*c*.

The flow-pressure characteristics of these systems, as seen by the control valve, are shown in Fig. 11. Nominal supply pressure P_s depends largely on the type of servo. Typical values are:

1. Up to 100 lb per sq in. for low power servos—industrial regulators, process controls, etc.
2. From 100 to 1500 lb per sq in. for medium power servos—machine tools, ordnance, etc.
3. From 1500 to 4000 lb per sq in. for high power servos—aircraft, missiles, etc.

Equation 3 shows that, if the pressure drop across a control valve is constant, flow rate depends upon valve displacement. This is an example of a flow-control valve, rather than a pressure-control valve. A bad feature is that much power is dissipated in the form of heat at the valve orifice. In fact, to achieve maximum power delivery to the system, one third of the total supply pressure P_s must be dissipated across the valve. This low efficiency offsets the basic simplicity of valve-controlled servos.

To avoid power dissipation and achieve high efficiency, variable-delivery pumps, Fig. 8, are often used instead of constant-delivery pumps plus control valves. The pumps are basically modified versions of the constant-displacement pumps previously discussed. Flow from a variable-delivery pump is approximately

$$Q = \frac{x}{L}\left(\frac{NV_p}{60}\right) = Kx \qquad (7)$$

where x = control lever displacement from no-flow position and L = maximum control lever displacement. Although the loads to operate the control lever are fairly considerable and cyclic, power needed to operate this lever is very small compared with the power delivered to the system.

BIBLIOGRAPHY

This article is the sixth in a co-ordinated group by J. M. Nightingale on servo systems. The previous articles and the issues of MACHINE DESIGN in which they appeared are:

1. "Automatic Control Systems" .....May 17, 1956
2. "Servo Mathematics" .....June 28, 1956
3. "Evaluating Servo System Performance—Part 1" .July 26, 1956
4. "Evaluating Servo System Performance—Part 2" ..Aug. 9, 1956
5. "Analyzing Servo Systems" .....Nov. 1, 1956

Tips and Techniques

Checking Pencils

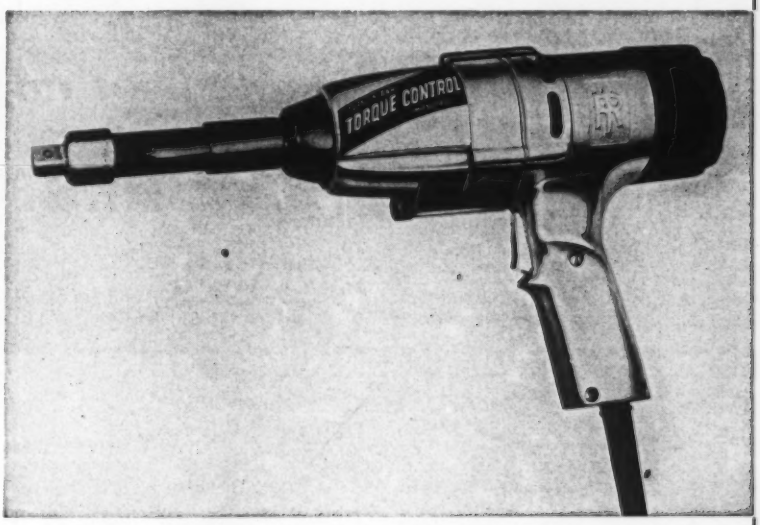
A technique which has proved to be very satisfactory when checking drawings is to use a green pencil for indicating correct dimensions, data, etc., and a red pencil for indicating incorrect information. To make the use of the two colors more convient, the pencils may be taped together as shown. —CHARLES E. GATES, *Bendix-Westinghouse Automotive Air Brake Co., Elyria, O.*

Protecting Drawings

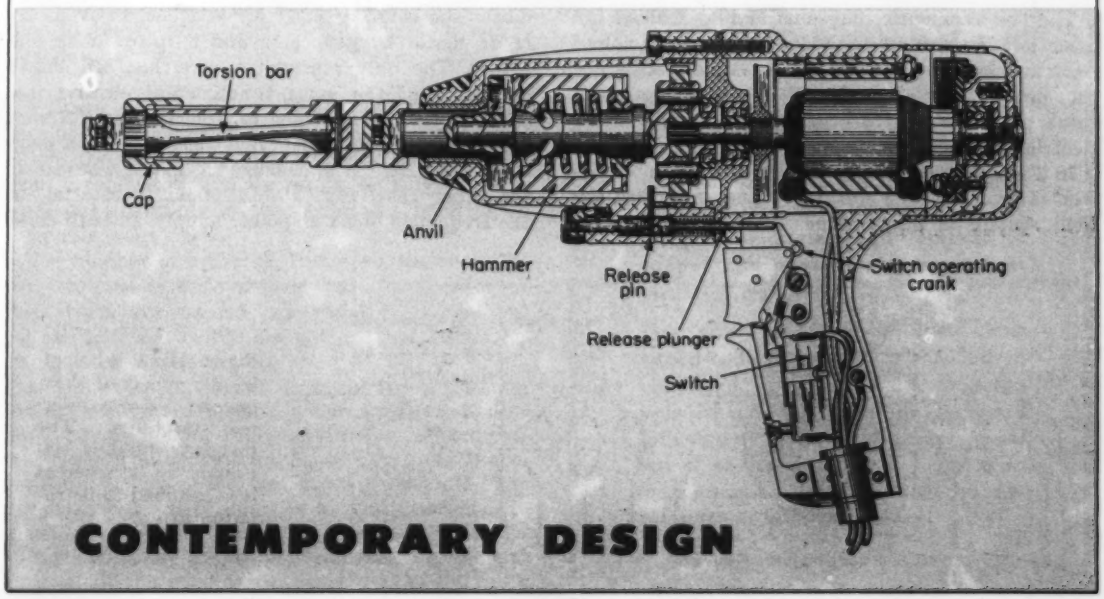
A light coat of acrylic plastic or lacquer sprayed on drawings will prevent their becoming smudged and dirty from continual use. The coating may become soiled but it can be easily wiped clean with a damp cloth or erased.—RICHARD L. BATES, *Small Aircraft Engine Dept., General Electric Co., West Lynn, Mass.*

Torsion Bar Controls Impact Tool Torque

AUTOMATIC shutoff when a preset torque is reached is an outstanding feature of a recently introduced electric impact tool. A product of Ingersoll-Rand Co., the tool is easily adjusted for torques from 20 to 90 lb-ft or may be used in conventional manner with no torque control. Full power is available in both directions of rotation so that either right-hand or left-hand threaded nuts or bolts may be tightened. The tool may also be used for drilling, wire brushing or hole sawing.



Torque-limiting action results from the torsion bar which functions like a solid member until preset torque is reached. When preset torque is reached, the torsion bar acts as a spring and is twisted a bit by the impact of the hammer on the anvil. Then, during the next portion of the cycle when the hammer is not exerting pressure on the anvil, the energy stored in the twisted torsion bar acts through the anvil against the hammer to force the hammer back far enough to contact the release pin. The release pin then forces the release plunger against a switch-operating crank to open the electrical circuit to the motor. Setting of the torsion bar is accomplished by first slipping the torsion bar cap far enough forward to disengage the splines in the cap from those on the torsion bar. Then, with a wrench, the torsion bar is twisted until the proper calibrating mark on the cap lines up with an index mark on the torsion-bar housing. The cap is then pushed back to engage the splines on the torsion bar.



Basic methods of adjusting speed in AC and DC Electric-

THE development of adjustable-speed drives, for which there has been rapidly increasing demand in recent years in almost all areas of original equipment design, has led to a large number of apparently different solutions of the problem. The variety of arrangements used tends to obscure the fact that they are all based on common fundamental principles of design and operation. This does not mean that the details of and differences between the types of machines used and their combinations are not of importance for their function and successful application; but just because of this, it is important to realize their basic inherent features.

A brief survey is presented here on the underlying common principles of practically all of the adjustable-speed drive systems using rotating dynamoelectric machines. It is usual to treat machines and circuits separately because of their alleged fundamental differences. In this article a different approach is taken, and the two systems are dealt with at the same time.

General Dynamoelectric Machine

The two schematic diagrams in Fig. 1 show the essential features of individual rotating dynamoelectric machines incorporated in the different schemes of adjustable-speed drives. In general, these circuits apply to practically all the possible electric rotating machines.

In Figs. 1*a* and 1*b* are shown the same fundamental machine. The stationary part is termed the field system in dc machines or the stator in ac units. The rotating assembly is called an armature in dc motor or generator and a rotor in ac machines. The only reason two sketches are shown in Fig. 1 of the same fundamental electric machine is that it is easier to describe the different functions by assuming in one case, Fig. 1*a*, a magnetic field that is stationary in space, whereas in the other case, Fig. 1*b*, the field is rotating at the frequency of an ac power supply. In both cases

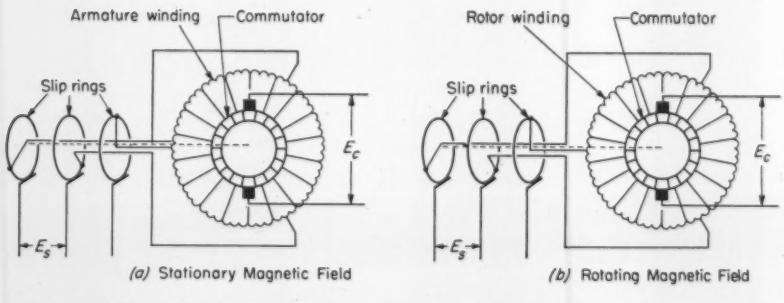


Fig. 1—Basic schematic diagrams of two general dynamoelectric machines. The magnetic field is stationary in *a* whereas it is assumed to be rotating in *b*.

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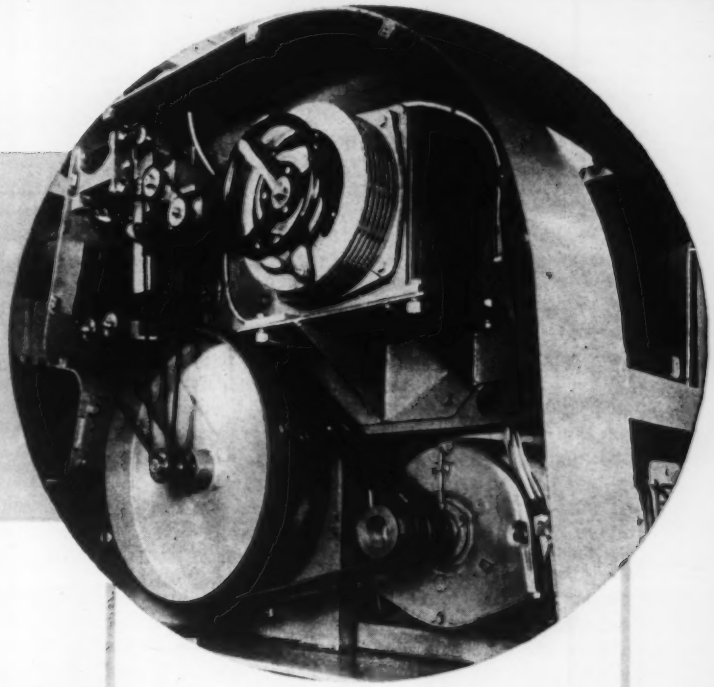
Norwich, England

Motor Drives



Speed of electric motors can be adjusted by:

1. **Changing the frequency, phase or voltage of electric power applied.**
2. **Changing impedance at certain points in the motor circuit.**
3. **Changing actual motor design, such as, reconnecting motor windings or shifting brushes.**

Most of the basic methods of speed control are well known. However, the host of drive-system variations and combinations are often difficult to remember and understand. This problem for the application or design engineer is further amplified by the alleged fundamental differences in control and operation of ac and dc electrical machines.

This article shows how each basic speed-control method is applied to either an ac or a dc motor. The only exceptions are methods of speed adjustment where the rotational speed of the stator field is changed in a manner that can only be accomplished with ac motors.

the electric rotating machine is shown with a commutator and a system of slip rings in its rotating part.

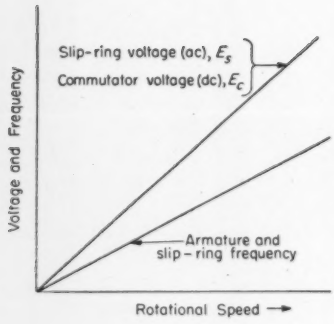
Commutators and Slip Rings: All electric motors or generators are basically ac machines. Apart from the squirrel-cage induction motor, which is not ordinarily an adjustable-speed motor in itself, it is generally necessary to provide an element to connect electrically the winding of the rotating part with some stationary apparatus or electric power supply outside the machine. Slip rings are suitable elements for this purpose in some circumstances and commutators in others. Both are required for some types of machines. In order to make the correct choice it is necessary to realize basically what happens in the rotating part of the general dynamo-electric machine.

Voltage and Frequency: Every time the rotating part of the machine in Fig. 1*a* completes one revolution, the direction of the magnetic field, as seen from a conductor in the rotating winding, changes from one direction to the other and back again completing one cycle.

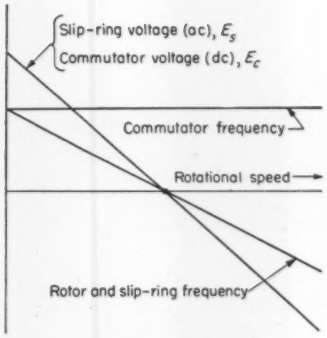
The number of cycles is, therefore, the same for the two-pole electric machine as the number of revolutions per second; as speed increases, the voltage induced by the changes of flux in the rotating part also increases.

A voltmeter connected between the brushes in contact with the slip rings, which are connected to fixed points of the rotating winding, will therefore register an ac voltage, E_s, of a magnitude proportional to the speed, as shown in Fig. 2*a*. The frequency of this voltage is also proportional to speed.

In contrast the segments of the commutator and the part of the winding connected to the segments



(a) Stationary Magnetic Field



(b) Rotating Magnetic Field

Fig. 2—Voltage and frequency characteristics at various points in the general dynamoelectric machine, The plot in *a* is for a stationary magnetic field; that in *b* is for the rotating field.

between any two stationary brushes change continually. The part of the winding, which at a particular time is connected between these brushes, remains in the same position in space irrespective of the speed of the rotating armature. Since this is the case, the magnetic field with regard to the part of the winding between these fixed brushes does not change its direction. A voltmeter reading at the commutator brushes will show that the direction of the voltage, E_c, remains constant, whereas its magnitude increases with the speed in exactly the same way as the slip-ring voltage.

The result is that at the commutator a dc voltage appears, but at the slip rings an ac voltage can be measured; both are proportional to the speed and both are, in principle, of the same magnitude, Fig. 2*a*.

Driven or driving, the dynamoelectric machine can therefore be used either as an ac or a dc generator or motor. The choice depends only on whether the slip rings or the commutator are utilized.

It is important to realize that in every type of dynamoelectric machine an ac voltage induced in at least one part and a commutator is needed to convert this ac voltage to dc if such is required. In the stationary field design, Fig. 1*a*, the rotating part receives an induced ac voltage.

In the general machine shown in Fig. 1*b* the speed of the rotating magnetic field is equal to the number of cycles of the multiphase power supply to which the stator winding is connected. This statement applies only to the machine shown which has one pair of poles. Since the rotating field always moves past two pole pitches during one cycle, in machines with more than one pair of poles the field rotates in space at an angular velocity inversely proportional to the number of pole pairs. For example, in a four-pole machine the field rotates in space with one-half the number of cycles as a two-pole design, and in a six-pole machine with one-third the number of cycles.

As long as the rotating part remains at standstill, the speed of rotation of the field, observed from the rotating part, is the same as seen from the stator and equals the supply frequency.

If the rotor revolves in the direction of rotation

Table 1—Types of Dynamoelectric Machines[1]

Slip rings	Commutator	Type of electric machine	Basic diagram
DC Excited Stationary Magnetic Field			
----	DC	DC motor or generator	
AC	----	Synchronous motor or alternator	
AC	DC	Rotary converter	
AC Excited Rotating Multiphase Magnetic Field			
AC	----	Induction motor[2] or generator	
----	----	Induction regulator[3]	
AC	----	Frequency changer	
DC	----	Synchronous motor or alternator	
----	AC	Stator-fed AC commutator motor[4]	
AC	AC	Frequency converter[5]	

1. Single phase ac rotating electric machines are not included.
2. Rotor winding is short circuited in squirrel-cage motors.
3. Slip rings are replaced by flexible connections.
4. An example of this type of motor is the Bogue N.S. variable-speed ac motor which can be designed with a shunt or series characteristic.
5. This drive is exemplified by the Bogue Speedmaster.

of the stator field, which is usually the case in practical applications, the frequency and magnitude of the voltage induced in the rotor winding decreases with increasing speed. Both are zero at synchronous speed where the rotor revolves at the same speed as the stator field. In this condition there is no relative speed between the stator field and the rotor, and no voltages are therefore induced in the rotor winding. If rotor speed is increased above the synchronous speed, voltage and frequency rise again in proportion to the difference between actual speed and synchronous speed.

A clear picture of conditions in the rotor winding of the general machine with a rotating stator field makes it easy to determine which voltage and frequencies will appear at the slip rings and at the commutator.

At the slip rings, which are connected to fixed tops in the rotor winding, the same voltages and frequencies must appear as in the rotor winding itself as shown in Fig. 2*b*. Slip-ring voltage and commutator voltage in Fig. 2*b* are of equal magnitude; both decrease from the standstill value and reach zero at synchronous speed and then increase above synchronous speed. Additionally, because of the commutator action, the part of the winding at any particular time between the stationary commutator brushes also remains stationary in space. Therefore, the frequency of the voltage at the commutator brushes is identical to that of the stator field. It will be shown later how this principle is utilized to obtain efficient speed variation with ac motors.

It must be realized that the machine in which the field in the stationary part is fixed in space, Fig. 1*a*, is only a special case of the application of the general machine in which the speed of rotation of the stator field is zero. Thus, the frequency at the commutator brushes is zero as well which means a dc voltage appears at the commutator brushes.

Types of Rotating Electric Machines

The general compilation in Table 1 provides a comprehensive picture of the whole field of rotating electric machinery. This table contains the possible combinations that can be directly derived from the general rotating electric machine with a stationary or rotating field. All known and practically used systems of rotating electric machines can be described in these terms and are in the table. Some machines not mentioned in Table 1 because they require constructional features not falling within the framework of this article survey can nevertheless be grouped within the general types of the table. The Scherbius machine and other phase advancers, for instance, which require a special field system fall under category of a stator-fed ac commutator motor. The Schrage motor, which requires two movable-brush systems on the commutator, falls under the frequency-converter category in Table 1. For the border-line case of the synchronous machine, both the stationary and rotating field types of general machines can be and are being used.

Electric-Motor Speed-Adjustment Methods

It is easy to visualize what to do to adjust speed if it is remembered that (1) in every electric circuit the voltages must be balanced, that is, the voltage applied to any winding must be equal and opposite to the voltage this winding generates, and (2) the voltage generated in the rotor winding is proportional to the flux or total strength of the magnetic field entering the rotor from the stationary part and the relative speed between the rotor winding and the magnetic field. Point 2

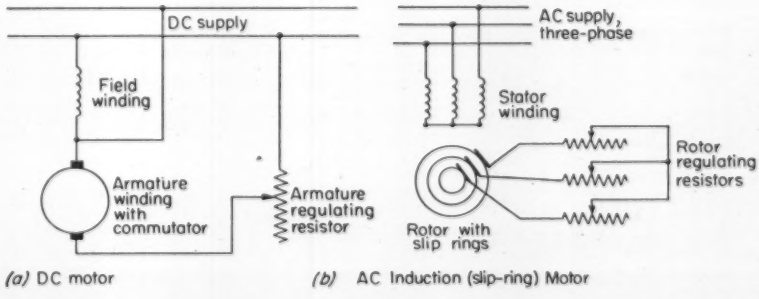


Fig. 3 — Method of motor speed adjustment where armature resistance is changed in a dc motor, *a*, or rotor resistance in an ac motor, *b*.

can be expressed in the following way:

> **Armature or rotor voltage** equals **machine constant** times **field flux** times **relative speed of armature or rotor** referred to stator field.

The machine constant contains the number of poles, the number of turns in the armature or rotor winding and, generally speaking, quantities that are inherent in the machine that cannot be altered under operational conditions. The only exception is the pole-change motor referred to later in which, through a change of stator-winding connections, the machine constant is operationally changed.

From the formula it is easy to derive three basic methods of changing the speed. These are:

1. Change of voltage applied to the armature or rotor winding.
2. Change of flux.
3. Change of rotational speed of the field in the stationary part.

There are of course combinations of different methods possible to which reference will be made as far as they are applied in practical use. First to be considered is speed adjustment through voltage variation in the armature or rotor. There are two basic ways to adjust armature or rotor voltage. One method is to insert resistance in the motor circuits. The other is to change the power-supply voltage. Resistance control will be discussed first.

Adjustable-Resistance Speed Control: The simplest way of varying voltage in the armature or rotor is to introduce resistance in that circuit. The voltage drop developed in a resistor by the load current changes voltage which in turn changes the motor speed. In Figs. 3*a* and *b* the application of this arrangement to a dc and an ac motor is shown.

In place of the slip rings shown, a commutator can be used also in the case of the ac machine, Fig. 3*b*, but this is not necessary since the frequency of the current in the resistance does not affect the function. In both cases there are heavy power losses in the resistors which are proportional to the amount of speed reduction. If for instance 33⅓ per cent speed reduction below the "natural" speed without resistance of either machine is required the losses in the resistance to obtain this lower speed are also 33⅓ per cent of the electrical input of the armature or rotor, which amounts to 50 per cent of the mechanical output at the shaft.

Since the voltage drop depends on the current in the resistance, a change of this current also changes the adjusted speed. The system is ineffective, without loading of the motor, with the result that when the load disappears the motor returns to its normal speed, and in case load changes, large speed changes occur.

Resistance speed regulation is therefore limited in its application, although it is fairly widely applied for intermittent and short-time speed adjustment. For example, it is applied in hoist and traction applications. Of course, resistance is used for starting purposes to control starting torque and current.

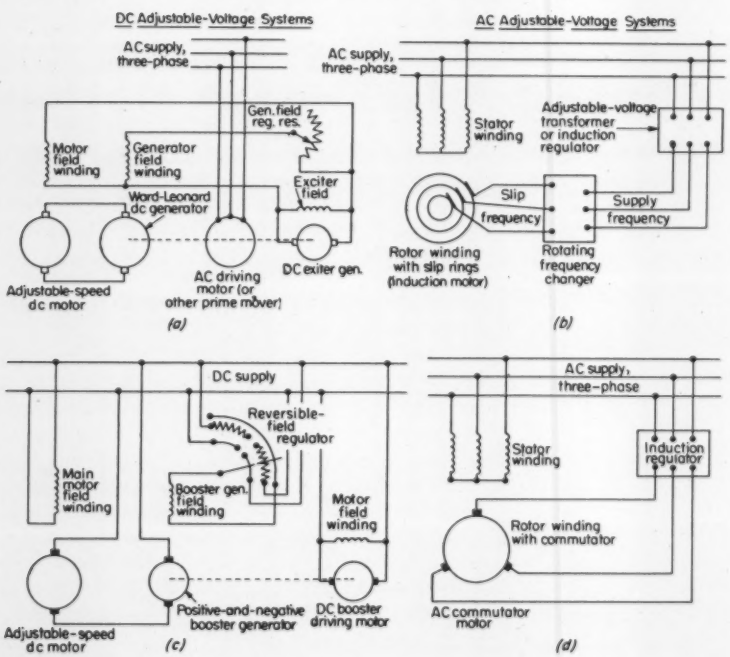


Fig. 4—Basic circuits for varying motor speed by adjusting voltage supplied to the motor. These include the Ward-Leonard system, *a;* a slip-ring motor controlled by a frequency changer in the rotor circuit, *b;* a positive - and - negative booster set, *c;* and an ac shunt commutator motor, *d.*

Adjustable-Voltage Speed Control: Voltage in adjustable-resistance motor controls depends on the load current, but voltage from an external power supply used for speed regulation is independent of load. Motors so regulated can be adjusted in speed independent of the load. Expressed in a different way, such motors have a shunt characteristic, that is, speed, once adjusted, does not vary materially with shaft load.

Two dc and two ac adjustable voltage arrangements of this kind are shown in Fig. 4. The Ward-Leonard system in Fig. 4*a* and the positive-and-negative booster arrangement in Fig. 4*c* have in principle the same function. The Ward-Leonard set can be utilized without requiring a main dc supply since the driving motor of the Ward-Leonard generator can be an ac motor, or any other prime mover. The positive-and-negative booster set requires a dc supply.

As is well known, in the Ward-Leonard set the voltage supplied from the generator to the adjustable-speed motor is changed by varying the field excitation of the generator. In the positive-and-negative booster arrangement the adjustable generator voltage is added to and subtracted from the dc supply voltage and this requires a reversal of field excitation in the process. The motor field is, in principle, kept constant, although combinations with motor field regulation are in use.

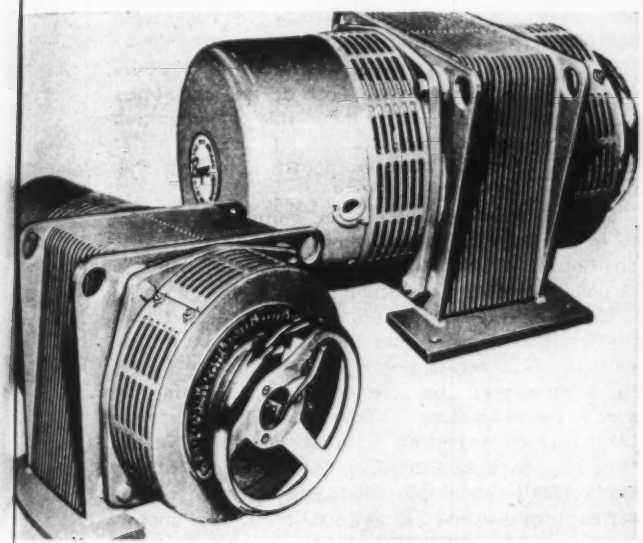


Fig. 5—Bogue N.S. variable-speed ac drives which are composed of two units—a commutator type wound-rotor motor and an adjustable induction regulator. Drives are available in horsepower sizes of ½ to 1000 speed ranges up to 30 to 1.

In Fig. 4*b* is the ac slip-ring motor with a frequency converter and an adjustable-voltage transformer in the rotor circuit. The adjustable-frequency supply is required in this case since the slip-ring voltage varies its frequency with the speed of the motor, Fig. 2*b*, and it is therefore necessary to introduce in the rotor circuit an adjustable voltage of the same frequency to obtain a workable arrangement. A Scherbius machine can, along with several other alternative systems, be substituted for the frequency converter shown in Fig. 4*b*.

The "loss free" speed regulation of the slip-ring motor requires additional rotating machinery. Its use has declined considerably in recent years and has been restricted in application to very large sets.

The introduction of a commutator in the ac motor, which converts the variable rotor frequency into a constant supply frequency, makes it possible to use the arrangement shown in Figs. 4*d* and 5. This design speed regulation is obtained by the introduction of an adjustable voltage of supply frequency into the rotor circuit. This adjustable voltage is produced by an induction regulator. This stator-fed ac commutator motor with shunt characteristic is trade named the N.S. variable-speed ac motor, Fig. 5.

It is impossible within this space fully to describe the different systems of induction regulators that are applied with the N.S. machine. It must, therefore, be sufficient to say that the induction regulator is in essence a stationary slip-ring induction machine, although in practice the slip rings are replaced by flexible connections since the rotor is not moved more than 180 degrees. One part, either stator or rotor, is connected to the supply and the other part, in principle, pro-

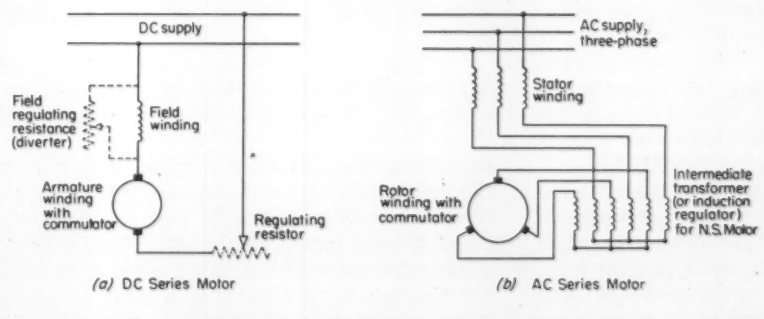


Fig. 6—Methods of adjusting speed of dc and ac series motors by controlling load current.

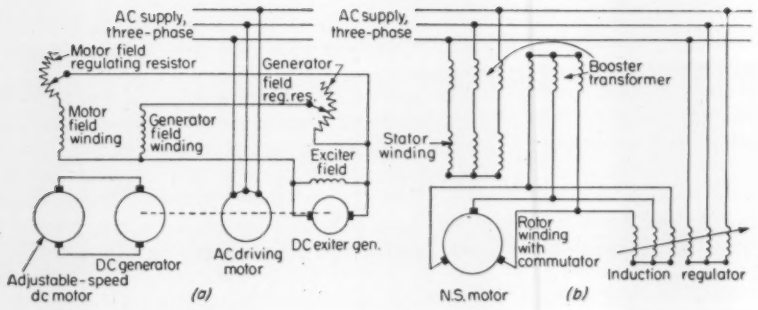


Fig. 7—Basic circuits of adjustable-speed drives with combination armature (or rotor) and field (or stator) voltage control. The Ward-Leonard system is shown in *a* and the N.S. variable-speed ac commutator motor in *b*.

duces the required variable voltage which is fed into the rotor circuit of the adjustable-speed motor.

As Fig. 2*b* shows, the voltage required to obtain speed variation increases with increasing difference of speed from the synchronous speed, which is in line with the general formula previously mentioned. The induction regulator has therefore to produce a voltage of the order of, and opposing, the rotor voltage to obtain low speed. The regulator voltage has to be gradually reduced so that at synchronous speed it becomes zero and has to be built up in the reverse direction to obtain speeds above the synchronous speed.

In this respect the arrangement in Fig. 4*d* is like the positive-and-negative booster set in Fig. 4*c*, the synchronous speed of the ac arrangement taking the place of the speed obtained when the variable booster voltage is zero, and the motor armature is fed with the constant dc supply voltage.

Field-Strength Speed Control for Series Motors: Change of field strength in series motors is brought about by the change of load current since load current flows in series through both the field or stator winding and the armature or rotor. This is, therefore, again a speed adjustment dependent on load but in principle "loss free." A definite speed-torque characteristic is obtained for any one adjustment of the relative field strength and load current. The connections for both dc and ac series motors are very simple as shown in Figs. 6*a* and *b*.

In the dc series motor the armature winding can be designed so as to allow the full supply voltage to be applied to it, whereas in the ac series motor it is generally necessary to have an intermediate transformer introduced between the stator and rotor circuit. Since the transformation ratio of this transformer is constant, the connection is a true series connection with the currents in the rotor and stator circuit always remaining proportional.

The speed of the series motor changes automatically with the load, which is a requirement in many traction or hoist type drives, in order to obtain automatic speed increase with light loads and, conversely, automatic speed decrease with heavy loads. It is also necessary to make provision for adjusting at will the speed-torque characteristic to produce different speeds at given loads. This can be done with both dc and ac series motors by introducing series resistance in the circuit, which of course causes losses and is therefore only used for intermittent operation ordinarily.

It is also possible to adjust the supply voltage for the same purpose with both dc and ac motors by various means. A common way of changing the torque-speed characteristic of the dc series motor is the field diverter, shown dotted in Fig. 6*a*.

In the ac series motor it is, moreover, possible to obtain such adjustment by changing the phase position between stator and rotor current. This can be done by shifting the brush gear.

If, as indicated in Fig. 6*b*, the intermediate transformer is replaced by an induction regulator, i.e., with the N.S. series motor, it is possible to adjust the torque-speed characteristic without having resort to brush shifting. This is a suitable and simple technique of adjusting without losses the speed of such drives as fans. The falling torque of fan loads results in stable conditions in spite of the series torque-speed characteristic of this motor.

Field-Strength Speed Control for Shunt Motors: The possibility of using an adjustable field resistance for varying the field excitation of a dc shunt motor is well known. This design is used, for instance, for the dc driving motor of motor-alternator sets in adjustable-frequency power supplies.

A similar possibility exists with a shunt ac motor, but this is only effective if the machine operates at speeds different from the synchronous speed.

Stator voltage regulation of the ac shunt motor is therefore in practice used only in combination with rotor voltage regulation. The principle, illustrated in Fig. 7*b*, can best be compared on the dc side with Ward-Leonard control combined with field regulation of a dc motor as shown in Fig. 7*a*. It will be seen from Fig. 7*b* that the voltage produced by the induction regulator is not only applied to the rotor of the N.S. motor, as in Fig. 4*a*, but through an auxiliary or booster transformer which is also introduced in the stator circuit. In

this way a voltage proportional to the adjusted induction-regulator voltage is added to or subtracted from the supply voltage fed into the stator winding. The continuous change of field so obtained in the ac motor can be usefully employed to achieve improved performance of this machine, especially where the load torque is not constant over the speed range.

In the dc arrangement, Fig. 7*a*, field weakening through the shunt-field regulator is generally employed to extend the speed range upward without having to increase the size of the Ward-Leonard set in those cases where constant output is sufficient in the upper part of the speed range.

While the field regulation of the ac motor can be utilized under the same conditions, that is, constant output over some part of the range, it is also possible with the ac arrangement to reduce the flux of the motor with reducing speed by introducing the boosting voltage in the stator circuit in the reverse direction. By this means a useful improvement of the performance, efficiency and power factor can be obtained with drives that require reduced torque at low speeds, like fans and pumps.

Speed Adjustment with Pole-Change Motors: This system of speed regulation is only applicable to ac motors but all machines used fall under the description of the general rotating electric machine as outlined in the first part of this article.

The most obvious way of changing the rotational speed of the magnetic field of the general machine in Fig. 1*b* is to change the number of poles of the stator winding. This has the effect that a constant-frequency supply system, say a 50-cycle supply, will produce a rotational field of an angular velocity in relation to the number of poles in the stator winding.

Two or more separate stator windings provided in the motor can alternatively be connected to the supply, causing the rotor, usually an induction-motor rotor, to revolve at corresponding speeds.

Instead of providing two or more different stator windings, it is also possible to change the connections of one and the same winding to alter the number of poles.

Frequently combinations of the two systems are used to obtain more than two speeds, but only a limited number of fixed speeds can be obtained by pole changing, and stepless speed variation is not possible with this system.

Speed Adjustment by Changing Supply Frequency: This speed-adjustment method, like the previous technique, is only applicable to ac motors.

By driving a dc-excited alternator at different speeds, a voltage varying in proportion to magnitude and frequency is produced in the ac alternator winding. In Fig. 8*a*, such an alternator is driven by a dc adjustable-speed motor with field regulation, so that the induction motor (or motors) supplied by the alternator will change their speed in accordance with its frequency, which is proportional to the speed of the motor-alternator set. This system allows squirrel-cage induction motors

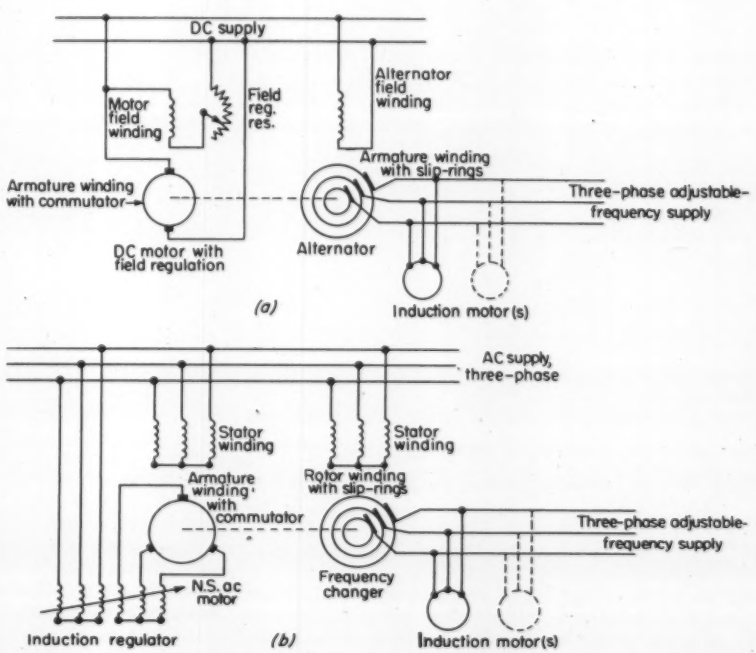


Fig. 8 — Adjustable-frequency method of changing speed in induction motors. A dc drive motor is used to drive the alternator in system *a* whereas an ac N.S. shunt commutator motor is applied in *b*.

to be used, for instance, on individual roller-table drives in steel mills where only a dc power supply is available, instead of applying a large number of small dc motors fed from a Ward-Leonard or positive-and-negative booster set to the individual rollers.

If the general rotating electric machine equipped with slip rings is driven at a speed different from its synchronous speed and its stator or rotor winding is connected to a constant-frequency system, the secondary winding will generally produce a voltage of a different frequency which can be utilized to feed induction motors.

By changing the speed of this frequency changer, the frequency produced by its secondary winding is also changed, Fig. 2*b*, and the speed of the induction motors supplied from the frequency changer varied accordingly.

This system is practical only if ac power is available; Fig. 8*b* shows an example of such a frequency changer driven by an ac variable-speed N.S. shunt motor.

This, and similar arrangements, have found their application where high speeds are required at the final motor shaft, and where it was found to be easier to construct a squirrel-cage motor for these high speeds than a commutator machine either of the ac or dc designs.

A simple, economical, and more efficient system of adjustable-frequency drive has been developed by using the general machine, which is physically an ac shunt commutator motor with the addition of slip rings, as an adjustable-speed self-propelling frequency converter, Fig. 9. This drive system, disregarding the induction motor connected to its slip rings, functions exactly in the same way as a light-running ac shunt commutator motor as shown in Fig. 4*d*. The speed is adjusted by rotor-voltage regulation by means of the induction regulator.

As will have become amply clear from the description of the behavior of the general machine, the frequency appearing at the slip rings on the rotor winding of the unit in Fig. 9 will vary in proportion with the difference between its speed and the synchronous speed, Fig. 2*b*. This adjustable frequency is again utilized to supply one or more induction motors which thereby become adjustable-speed motors.

Since the drive armature functions as a converter only because the commutator and slip-ring currents cancel each other in a way similar to a rotary converter, the size and losses of the adjustable-speed drive are small in comparison with its output. A most efficient and economical system of conversion of a constant into an adjustable-frequency supply is obtained in this way. Since any number of motors can be connected to the slip rings, simultaneous speed adjustment of squirrel-cage motors over wide speed ranges is possible.

Summary Remarks

The problem of commutation has been almost completely solved many years ago with dc machines by the introduction of interpoles which are readily applicable only to machines with stationary field. This has given the dc technique a flying start, whereas the commutation of ac machines with rotating fields had for many years been an obstacle in the way of developing similar systems of adjustable-speed ac drives that are usable in practice.

Only with the advent of new arrangements of the rotor winding, mainly the development of a suitable commutating winding which is parallel connected to the main rotor winding, have these difficulties been overcome, and the way opened to a rapid development of ac adjustable-speed drives. Thus, commutation with ac machines is no more of a problem today than with dc machines.

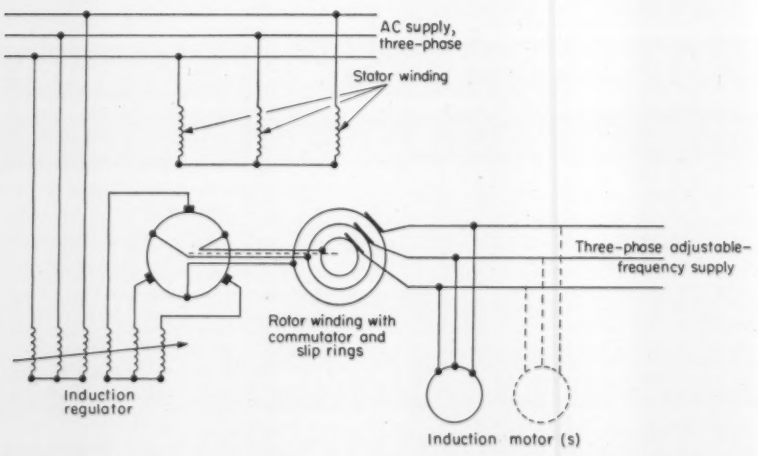


Fig. 9—An adjustable-frequency drive employing an ac shunt-commutator motor which is also designed with slip rings. Tradenamed Speedmaster, the drive is actually an adjustable-speed, self-propelling frequency converter. The induction regulator controls rotor voltage and, in turn, speed.

Design charts and equations for controlled

Epicyclic Gear Systems

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Purdue University,
Lafayette, Ind.

RECENT emphasis on features of automatic operation in machine drives has focused attention on the unique and varied possibilities offered by epicyclic gear systems with branch control circuits, Fig. 1. However, design and development of these systems have been hampered by difficulties encountered in visualizing required kinematic arrangements for different applications, and in predetermining circulating power loads in the branch circuit.

Design equations and a method for determining the amount of circulating power in epicyclic gear systems with branch control circuits were established in a previous article.* This article presents techniques and design charts for simplified analysis of such systems for specific applications.

The general type of system under consideration

*H. G. Laughlin, A. R. Holowenko and A. S. Hall—"Epicyclic Gear Systems," MACHINE DESIGN, Vol. 28, No. 6, March 22, 1956, Pages 132-136.

Nomenclature

N = Number of teeth in gear
P = Power, hp
P_i, P_o = Input and output power, respectively, hp
P_{cir} = Circulating power in branch control circuit, hp
Q = Relative velocity ratio, Equation 7
R = Velocity ratio, Equation 2
r = Velocity ratio, Equation 3
X = Arbitrary relative velocity ratio, Equation 9
γ = Power ratio, Equation 1
ω = Angular speed, rpm
ω_a = Absolute angular velocity of differential arm (Fig. 2), rpm
ω_i, ω_o = Angular speeds of input and output members, respectively, rpm
ω_x, ω_y = Absolute angular velocities of differential gears (Fig. 2), rpm

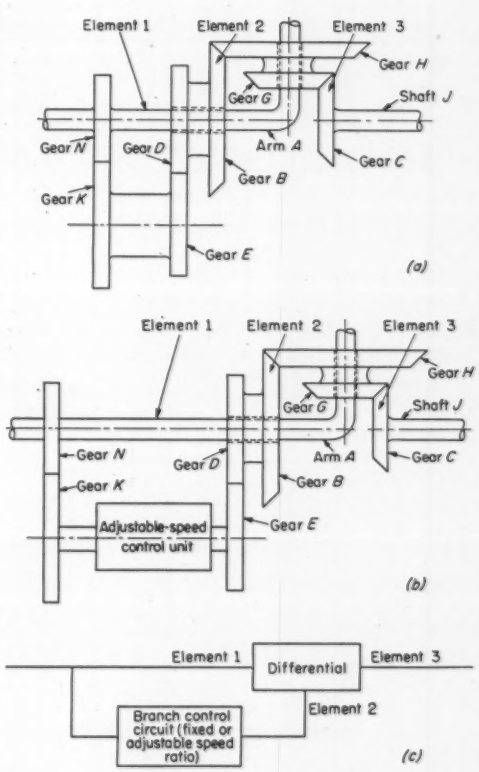


Fig. 1—Typical epicyclic gear systems with branch control circuits showing, *a*, fixed-ratio gear train in branch circuit, *b*, adjustable-speed unit in branch circuit and, *c*, simplified system diagram for analysis of power flow.

is illustrated in Fig. 1*a*. Speed ratio of arm, or shaft, *A* and shaft *J* is influenced by gears *N*, *K*, *E* and *D* in the branch circuit. If the speed ratio of gears *N* and *D* is varied, speed relationship of arm *A* and shaft *J* will be affected.

One method of controlling the speed relationship of arm *A* and shaft *J* is by means of an adjustable-speed unit in the branch circuit, Fig. 1*b*. However, there are practical limitations to such drive arrangements. Under certain combinations of speed and power, the elements of the branch circuit may be subjected to large torques. Required capacity of the adjustable-speed unit, from the standpoints of both power and range of speed adjustment, can be determined for any particular application from the design charts provided here.

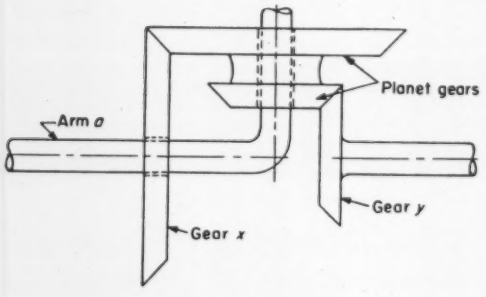


Fig. 2—Simple bevel-gear differential design for controlled epicyclic gear systems. Angular velocity relationships for this basic arrangement are given by Equation 6.

Design Equations and Charts: In the following analysis, effect of friction has been neglected. However, efficiency of the system must, of course, be taken into consideration in the final design.

A differential transmission having a branch control circuit is shown schematically in Fig. 1*c* to establish how the three basic elements 1, 2 and 3 are defined. Element 3 leaves the differential with no external connections, while element 2 is controlled by means of a branch control circuit connecting elements 1 and 2. Elements 1 and 3 are either the main input or output to the differential, while a certain amount of circulating power will be flowing through element 2.

The ratio, γ, of the power flowing through element 2 to the power flowing through element 3 for the arrangement shown in Fig. 1*a* was defined in the previous article as

$$\gamma = \frac{\omega_2 (\omega_3 - \omega_1)}{\omega_3 (\omega_1 - \omega_2)} = \frac{r (1 - R)}{1 - r} \qquad (1)$$

where

$$R = \frac{\omega_1}{\omega_3} \qquad (2)$$

$$r = \frac{\omega_2}{\omega_1} \qquad (3)$$

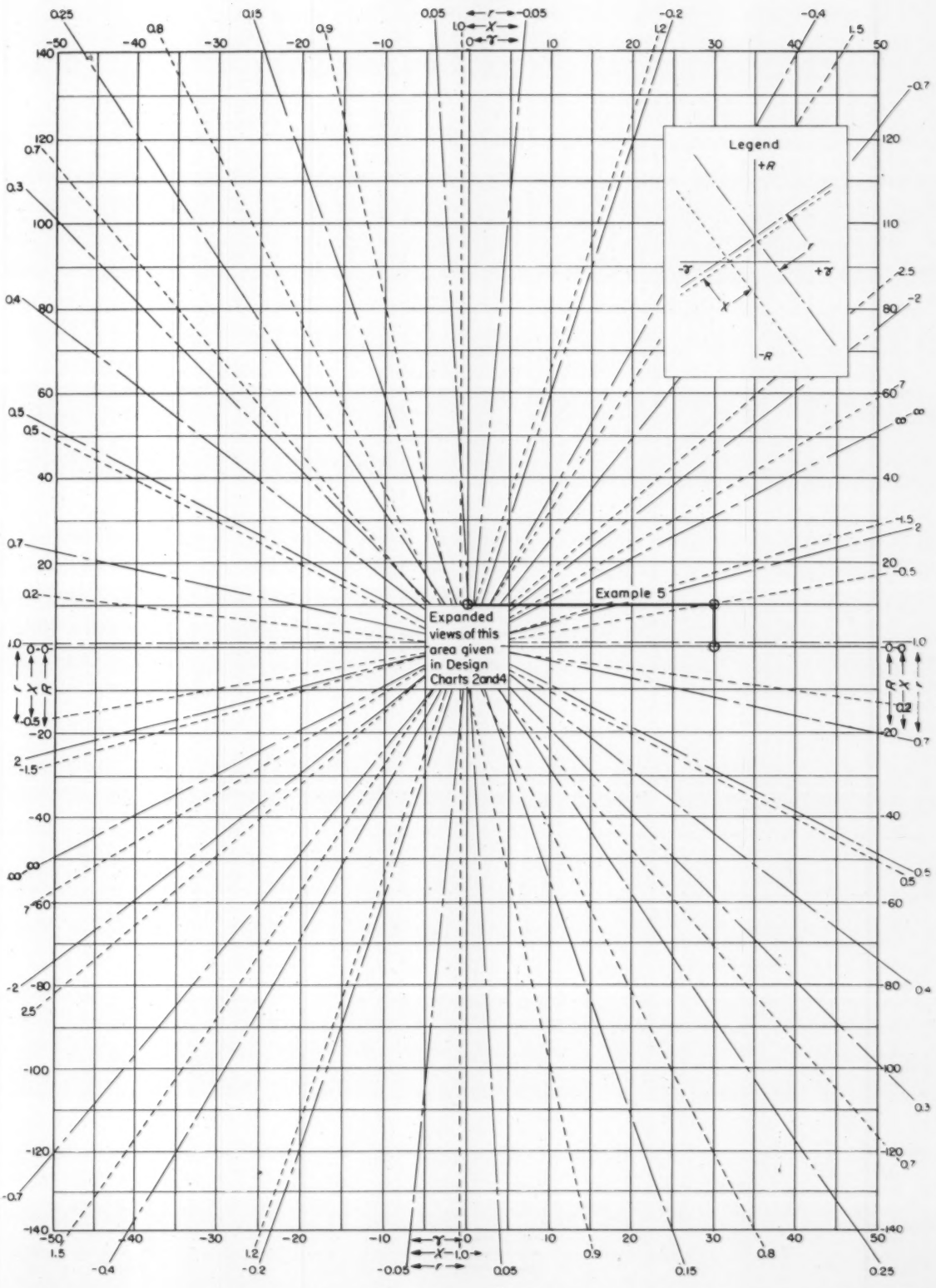
Symbols are given in the Nomenclature and subscripts identify individual elements.

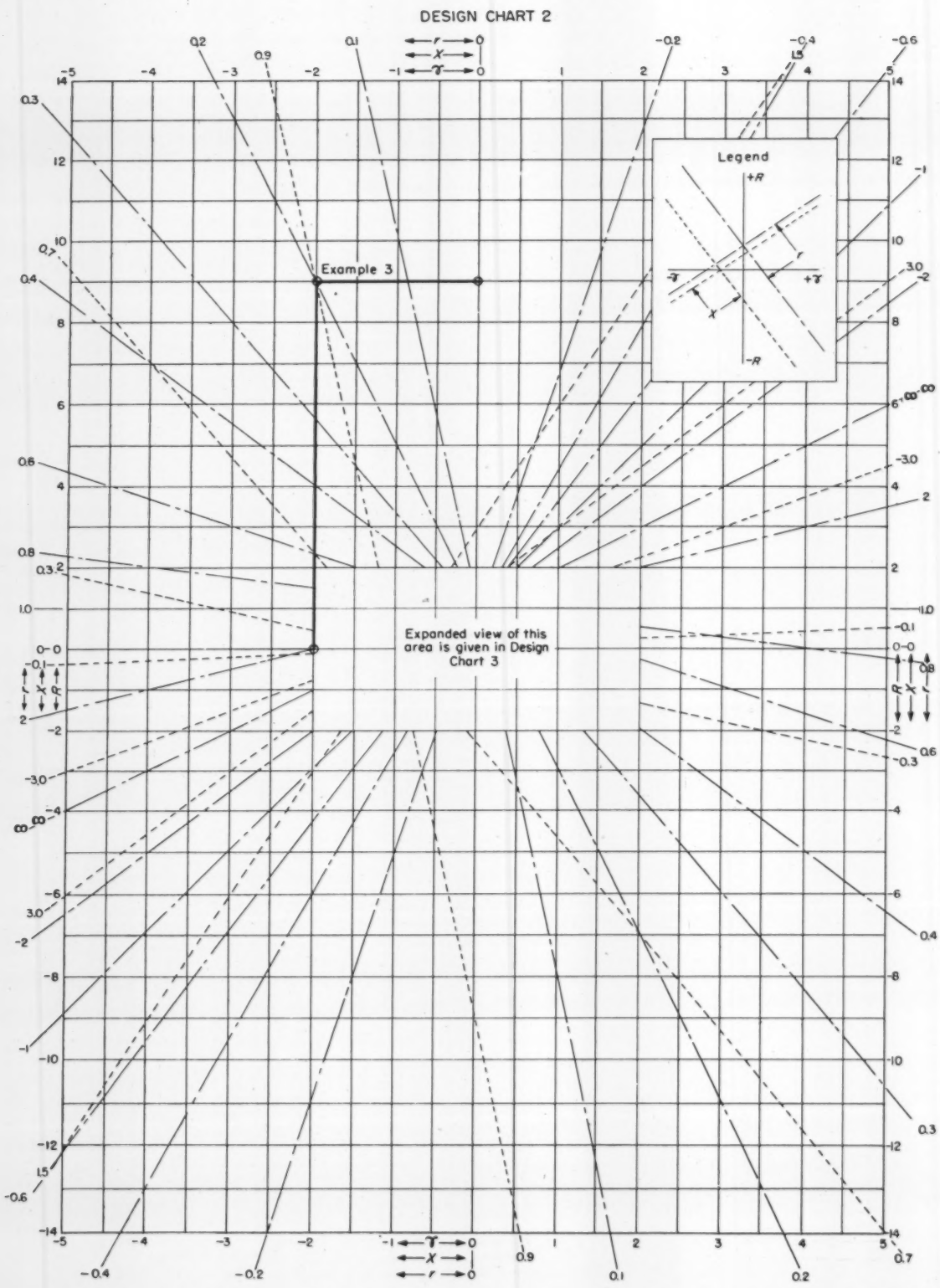
Equation 1 may also be written:

Table 1—Velocity Relationships

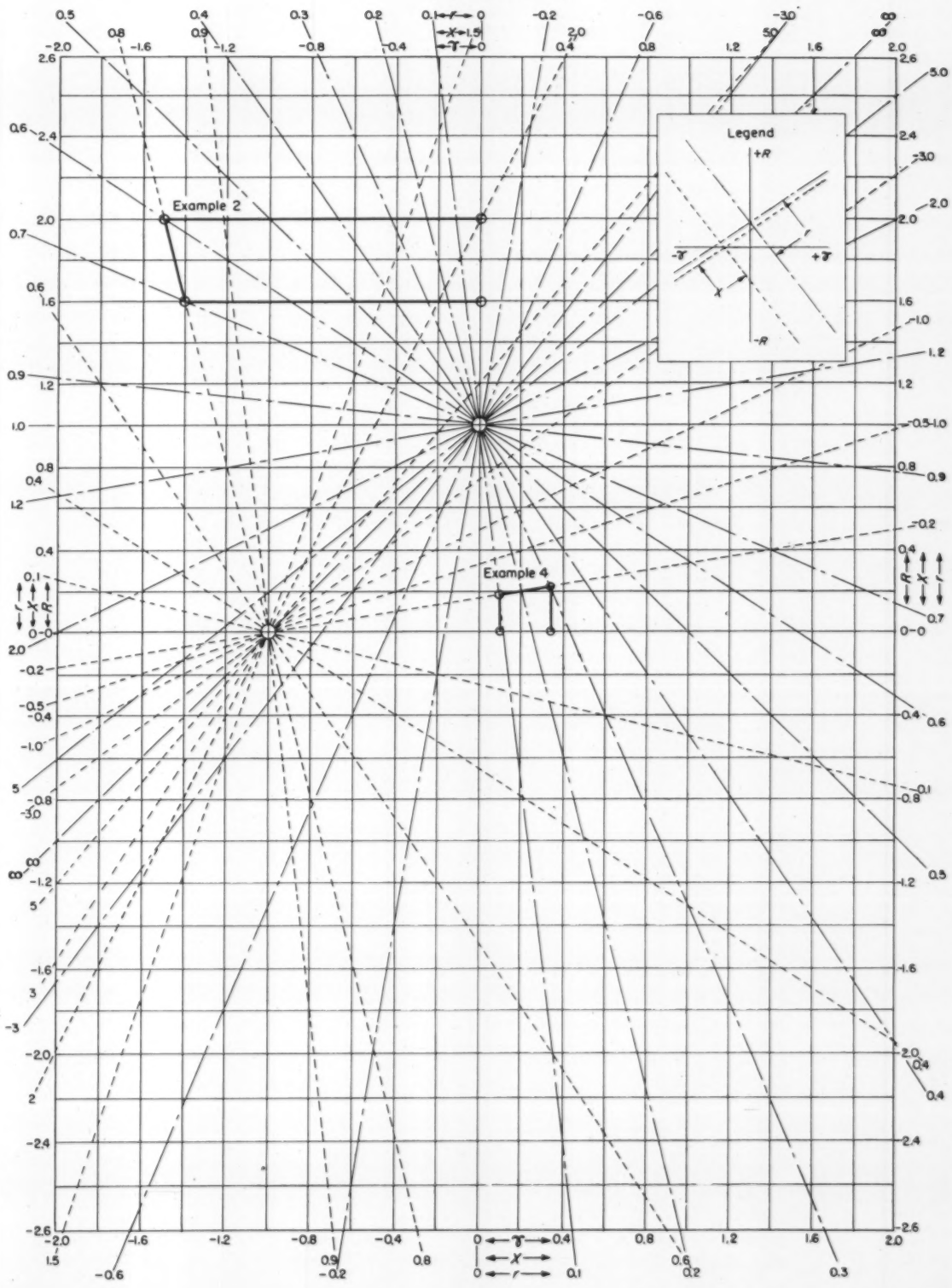
Case	Arrangement of System Elements			Velocity Equation (Eq. 6)	X	Q
	Arm *a*	Gear *x*	Gear *y*			
I	1	2	3	$\omega_2 = \omega_1 + (\omega_3 - \omega_1) Q$	Q	X
II	1	3	2	$\omega_3 = \omega_1 + (\omega_2 - \omega_1) Q$	$\frac{1}{Q}$	$\frac{1}{X}$
III	2	1	3	$\omega_1 = \omega_2 + (\omega_3 - \omega_2) Q$	$\frac{Q}{Q-1}$	$\frac{X}{X-1}$
IV	2	3	1	$\omega_3 = \omega_2 + (\omega_1 - \omega_2) Q$	$\frac{1}{1-Q}$	$\frac{X-1}{X}$
V	3	2	1	$\omega_2 = \omega_3 + (\omega_1 - \omega_3) Q$	$1-Q$	$1-X$
VI	3	1	2	$\omega_1 = \omega_3 + (\omega_2 - \omega_3) Q$	$\frac{Q-1}{Q}$	$\frac{1}{1-X}$

DESIGN CHART I




DESIGN CHART 2
Legend
+R
-R
+Y
-Y
r
X
Example 3
Expanded view of this area is given in Design Chart 3

DESIGN CHART 3



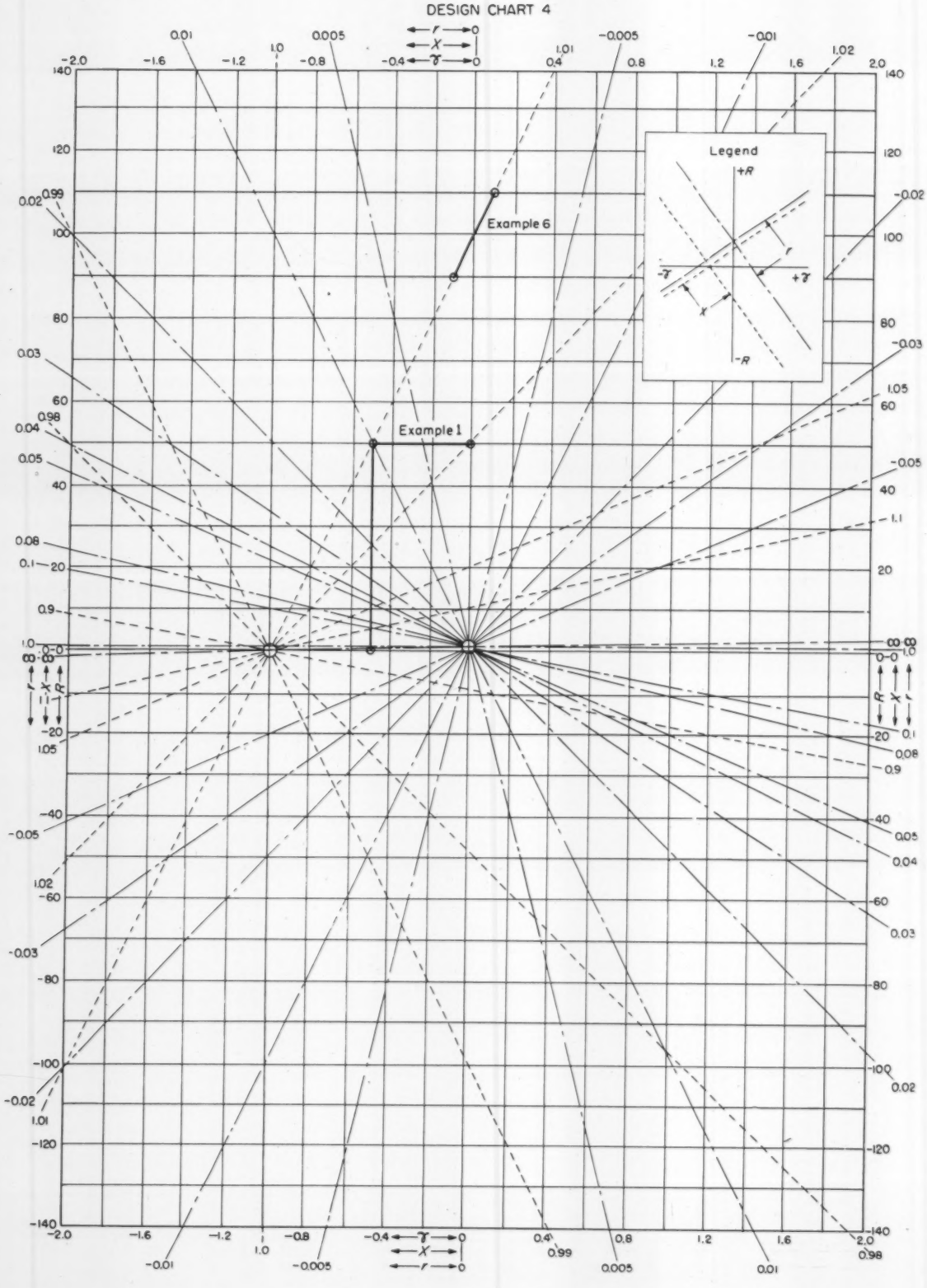
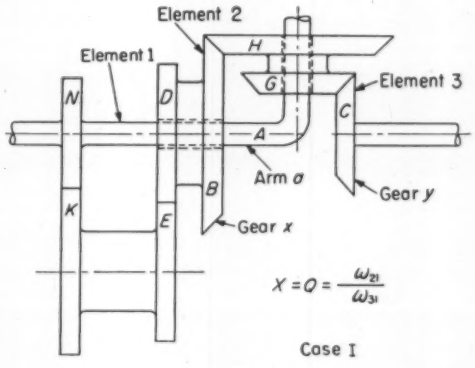
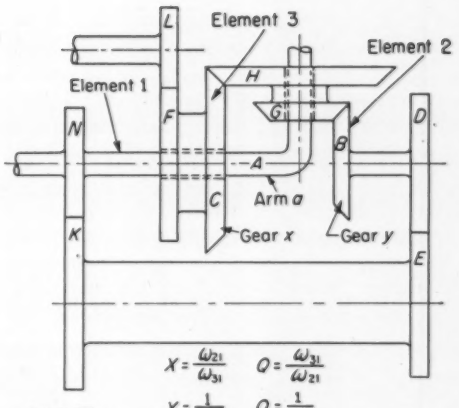

DESIGN CHART 4
Legend
+R
-R
Example 6
Example 1

Fig. 3—Basic design arrangements for epicyclic gear systems with branch control circuits.



$$X = Q = \frac{\omega_{21}}{\omega_{31}}$$

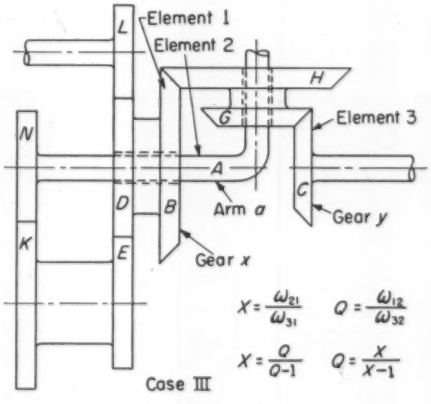
Case I



$$X = \frac{\omega_{21}}{\omega_{31}} \quad Q = \frac{\omega_{31}}{\omega_{21}}$$

$$X = \frac{1}{Q} \quad Q = \frac{1}{X}$$

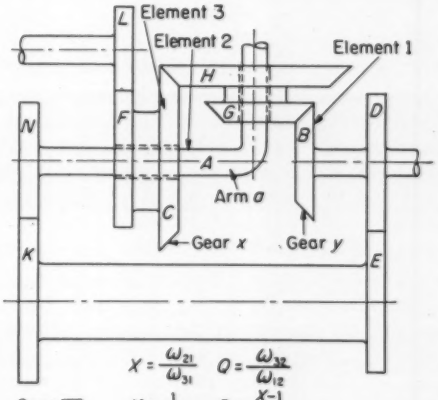
Case II



$$X = \frac{\omega_{21}}{\omega_{31}} \quad Q = \frac{\omega_{12}}{\omega_{32}}$$

$$X = \frac{Q}{Q-1} \quad Q = \frac{X}{X-1}$$

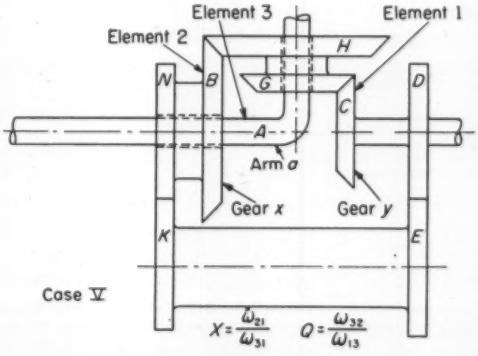
Case III



$$X = \frac{\omega_{21}}{\omega_{31}} \quad Q = \frac{\omega_{32}}{\omega_{12}}$$

$$X = \frac{1}{1-Q} \quad Q = \frac{X-1}{X}$$

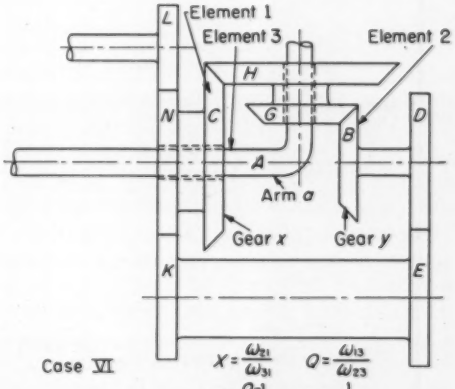
Case IV



$$X = \frac{\omega_{21}}{\omega_{31}} \quad Q = \frac{\omega_{32}}{\omega_{13}}$$

$$X = 1-Q \quad Q = 1-X$$

Case V



$$X = \frac{\omega_{21}}{\omega_{31}} \quad Q = \frac{\omega_{13}}{\omega_{23}}$$

$$X = \frac{Q-1}{Q} \quad Q = \frac{1}{1-X}$$

Case VI

$$R = \gamma \frac{r-1}{r} + 1 \qquad (4)$$

Equation 4 represents a family of straight lines, having slopes $(r-1)/r$ and a common intercept of $+1$ on the R ordinate when plotted in terms of R and γ as shown in Design Charts 1, 2, 3 and 4. These lines, as plotted on the charts, are constant r lines. They can be used, as will be demonstrated later, for determining the amount of circulating power flowing through the branch control circuit, or through element 2 since

$$P_{cir} = P_2 = \gamma P_3 \qquad (5)$$

For the general case of a differential containing two rotating gears, which may be interconnected by planetary gears carried on an arm, Fig. 2, angular velocity relationships are given by the vectorial equation,

$$\omega_x = \omega_a + (\omega_y - \omega_a)\, Q \qquad (6)$$

where Q is the relative velocity ratio. This ratio is defined by

$$Q = \frac{\omega_{xa}}{\omega_{ya}} \qquad (7)$$

where ω_{xa} and ω_{ya} represent angular velocities, relative to the arm, of gears x and y, respectively.

For an epicyclic system of the type shown in Fig. 1*a*, six specific velocity equations are possible, depending upon which of the three system elements, 1, 2 and 3, correspond to members a, x and y of the general expression, Equation 6.

As an aid to analysis, an arbitrary quantity, X, will be introduced. This quantity can be readily established from any one of the six possible velocity equations; the following equation has been selected arbitrarily for the purposes of this article:

$$\omega_2 = \omega_1 + (\omega_3 - \omega_1)\, X \qquad (8)$$

Thus, by definition (Equations 6 and 7),

$$X = \frac{\omega_{21}}{\omega_{31}} \qquad (9)$$

Combining Equations 1, 2, 3 and 9 gives an expression for X as a function of R, r, and γ:

$$X = -\frac{Rr}{\gamma} \qquad (10)$$

From Equation 4 then, substituting for r,

$$R = \frac{X}{X-1}(\gamma + 1) \qquad (11)$$

Equation 11 represents a family of straight lines, having slopes of $X/(X-1)$ and intercepts of -1 on the γ axis in Design Charts 1, 2, 3 and 4. These lines, which are plotted as constant X lines, are related to the number of teeth in the gears of the differential.

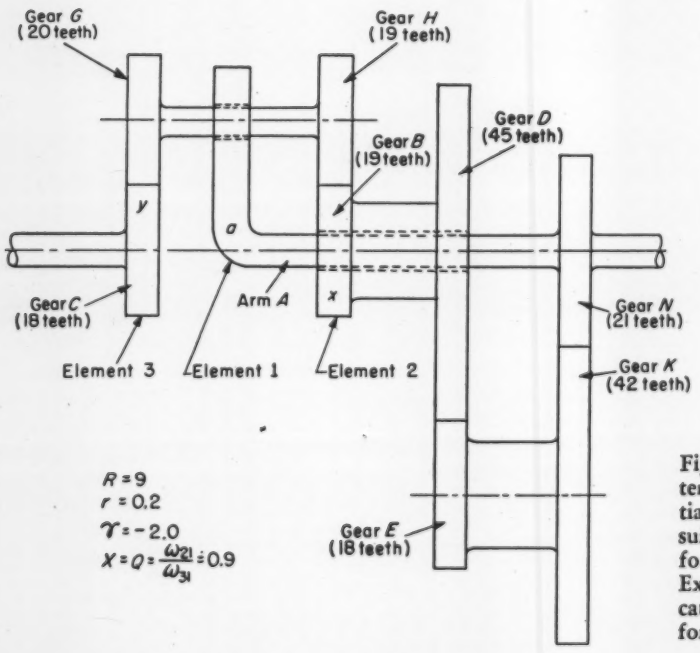


Fig. 4—Epicyclic gear system with spur gear differential. This system offers a suitable alternate solution for the design conditions of Example 3 and is a modification of the arrangement for Case III in Fig. 3.

It is now necessary to determine the relationship between Q of the general vectorial expression (Equation 6) and X for specific epicyclic system arrangements. As previously pointed out, there are six possible ways of expressing Equation 6 in terms of elements 1, 2 and 3, depending on the function of each of these elements in the specific system arrangement. These six cases along with the corresponding velocity equations and relationships between Q and X are given in Table 1. Typical system arrangements for each of the cases are shown in Fig. 3.

The relationships between Q and X, Table 1, can be readily determined for each case from an analysis of the individual velocity equations. From Equation 8, it will be seen that Case I was used here to define the factor X. Thus, for Case I, $Q = X$.

Similar relationships can now be established for the five remaining cases by rearranging each of the velocity equations in the form of Equation 8. For example, in Case II the velocity equation becomes:

$$\omega_2 = \omega_1 + (\omega_3 - \omega_1)\frac{1}{Q}$$

For Case II then, $X = 1/Q$ or, inversely, $Q = 1/X$. Repeating this procedure for each of the four other cases establishes the relationships given in Table 1.

It should be noted that Q is a function of the number of gear teeth or train ratio across the differential of the epicyclic system. Also, since X is a function of Q for the six system arrangements in which the differential may be used, X and Q both remain constant for any specific differential design employed with a given arrangement.

To further clarify the design relationship between Q and X, it will perhaps be helpful to consider the typical epicyclic gear system for Case I shown in Fig. 3. Here, in accordance with the previous definition, the velocity expressions for Q and X are equal. In this arrangement, gear B is element 2 (Fig. 1c), gear C is element 3 and arm A is element 1. Velocity expressions for the remaining five system arrangements shown in Fig. 3 also bear out the relationships previously established for Q and X, Table 1.

It should be noted that for all six cases shown in Fig. 3, $Q = (N_C/N_G)(N_H/N_R)$. Also, note that Q must be negative for all of these arrangements as shown.

Although a simple bevel gear differential has been used for illustration in the foregoing analysis, the methods and equations presented here apply to any epicyclic gear system with a branch control circuit.

Example 1: Determine the amount of circulating power in the branch circuit of an epicyclic gear system. Design conditions are: $R = +50$, $\omega_o = \omega_3 = 100$ rpm, $P_o = P_3 = 60$ hp, $r = +0.01$ and $\omega_i = \omega_1 = 5000$ rpm.

From Design Chart 4 at the point corresponding to $R = +50$ and $r = +0.01$, $\gamma = -0.495$. From Equation 5, $P_{cir} = -0.495\ (60) = -29.7$ hp. The negative sign indicates that the circulating power flows through the branch circuit and into the differential through element 2, since the power flows out of the differential through element 3.

Example 2: Determine speed range and power requirements for an adjustable-speed transmission in the branch control circuit of an epicyclic gear speed-reducer system. Design conditions are: $P_o = P_3 = 10$ hp; $\omega_i = \omega_1 = 3600$ rpm (constant); $\omega_o = \omega_3$ is to vary from 1800 rpm minimum to 2250 rpm maximum; input and output shafts rotate in same direction; and minimum speed ratio of the transmission across the branch circuit is to be limited to $r = 0.6$.

Design Chart 3 will be used for the solution. From Equation 2, R varies from $+2$ for $\omega_3 = 1800$ rpm to $+1.6$ for $\omega_3 = 2250$. In Design Chart 3, the point corresponding to $R = +2$ and $r = +0.6$ is located. At this point, which represents the minimum speed condition, $\gamma = -1.5$.

It will be noted that this point lies on the $X = 0.8$ line. To find the maximum speed condition, this constant X line is followed downward and a second point is located at $R = +1.6$. At this point, $r = 0.7$ and $\gamma = -1.4$.

Thus, speed ratio of the adjustable-speed transmission in the branch circuit must vary from 0.6 to 0.7, a range of 1.17:1. From Equation 5, maximum and minimum power requirements, P_{cir}, for the branch circuit will be 15 and 14 hp, respectively.

Example 3: Determine basic design details and a suitable system arrangement for an epicyclic gear speed reducer in which the circulating power is to be twice the output power. Design conditions are: $\omega_i/\omega_o = R = 9$, and input and output shafts rotate in same direction.

Design Chart 2 will be employed for the solution. From this chart, it will be seen that both r and X can have either of two values, depending on whether design is based on $\gamma = -2.0$ or $\gamma = +2.0$. The former value, $\gamma = -2.0$, will be used here. From Design Chart 2 then, $r = +0.2$ and $X = +0.9$.

A suitable epicyclic gear arrangement can now be selected. Since r is positive, elements 1 and 2 must rotate in the same direction. Similarly, since R is positive, elements 1 and 3 must rotate in the same direction. Also, since X is positive, the ratio, ω_{21}/ω_{31}, must be positive.

Thus, for all of the system arrangements shown in Fig. 3, the value of Q is negative. As a result, the four arrangements shown for Cases I, II, V and VI cannot be used here because it would be

impossible to obtain a negative value of Q for $X = +0.9$. However, either of the other arrangements, Cases III and IV, would be suitable. For Case III, $Q = -9$, and for Case IV, $Q = -1/9$.

If the system arrangement for Case III is selected, the following design conditions, with elements 1 and 2 rotating in the same direction, must be satisfied:

$$r = \frac{N_D N_K}{N_E N_N} = 0.2$$

$$Q = \frac{N_C N_H}{N_G N_B} = |9|$$

The following tooth numbers will satisfy these conditions: $N_L = 21$, $N_D = 21$, $N_E = 42$, $N_K = 18$, $N_N = 45$, $N_C = 45$, $N_G = 15$, $N_H = 45$ and $N_B = 15$. Teeth of different pitch must be used in the gears of the differential to satisfy dimensions.

Another system arrangement, which employs a spur gear differential and will also satisfy the original design conditions, is shown in Fig. 4.

Example 4: Determine the required speed ratio range of an adjustable-speed transmission to be used in the branch circuit of an epicyclic gear system. Design conditions are: Input speed ($\omega_i = \omega_1$) is to be held between 0.18 and 0.22 times the output speed ($\omega_o = \omega_3$); input and output shafts rotate in the same direction; and P_{cir} is to be limited to 0.34 times the output power ($P_o = P_3$).

From Equation 2, R varies from $+0.18$ to $+0.22$. From Equation 5, $\gamma = +0.34$ maximum. Then from Design Chart 3, at the point corresponding to the high input speed condition of $R = +0.22$ and $\gamma = 0.34$, $X = -0.2$ and $r = +0.3$. Since X is constant for a given differential design, a second point for the low input speed condition can be found along the $X = -0.2$ line at $R = +0.18$. At this point, $r = 0.1$ and $\gamma = 0.1$.

Thus, the adjustable-speed transmission should provide a speed ratio range of 3:1, from $r = 0.1$ to $r = 0.3$.

Example 5: Determine design characteristics of an epicyclic gear reduction system in which the branch circuit is to be used to test machine elements under a load of 300 hp with a system power source of 10 hp.

From Equation 5, $\gamma = 30$. A value of $R = 10$ will be assumed. From Design Chart 1, at $\gamma = 30$ and $R = 10$, $X = -0.5$ and $r = +1.5$. These values are only approximate. For more exact results, the equations will have to be used. From Equation 4, $r = 1.43$. From Equation 10, $X = -0.477$.

Example 6: Determine basic design details for an epicyclic gear speed changer having an adjustable-speed transmission across the branch circuit. Design conditions are: P_{cir} is to be limited to 0.1 P_o and ω_i may vary from $90\omega_o$ to $110\omega_o$.

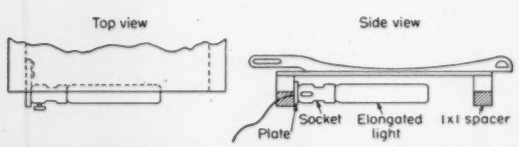
Design Chart 4 will be used for the solution. From Equation 2, R may vary from $+90$ to $+110$. From Equation 5, γ may have values of $+0.1$ or -0.1. Since X remains constant for a given differential, the relationship of the different variables may be readily established by examination of Design Chart 4. When $R = +90$ and $\gamma = -0.1$, $X = 1.01$ approximately and r is approaching zero. For exact results the equations will have to be used. From Equation 4, $r = 0.001125$. From Equation 10, $X = +1.01$. Similarly, when $R = 110$ and $\gamma = +0.1$, $r = -0.000918$ and $X = +1.01$.

Thus, the required speed range for the adjustable-speed transmission across the branch circuit will be $0.001125/-0.000918 = -1.225{:}1$. An auxiliary gear train in the branch circuit will be necessary to provide the extreme velocity ratios of $r = 0.001125$ and $r = -0.000918$. In this example, it should be noted that r and γ change sign in passing through zero.

Tips and Techniques

Improved Paper Cutter

An elongated light bulb installed below the cutting edge of a paper cutter will improve cutting accuracy. The shadow cast on the print or paper to be cut allows very accurate alignment of cutting edge and the cutting line.—FELIX A. KURTH, *North Wales, Pa.*



Pencil Holder

An automobile distributor cap can serve as a very convenient pencil holder. Caps from six-cylinder engines will hold seven pencils. Those from eight-cylinder engines will hold nine. To increase convenience the cap may be mounted to rotate. Each hole could be marked for a particular weight of lead. The holder may be painted any color.—CHARLES H. DERN JR. *Philadelphia, Pa.*

DESIGN ABSTRACTS

Metal-Ceramic Friction Materials

for clutches and brakes

By W. H. DuBois
Bendix Products Div.
Bendix Aviation Corp.
South Bend, Ind.

METAL-CERAMIC friction materials are, as the name implies, compositions of metal and ceramic particles. In developing such a material for use in heavy-duty clutch and brake applications, Bendix has found that certain characteristics are desirable.

A good friction material should have all of the following properties:

1. Adequate mechanical strength through all operating temperatures.
2. Temperature and thermal shock resistance.
3. High heat-absorbing capacity, i.e., high specific gravity, specific heat, and thermal conductivity.
4. High and consistent coefficient of friction.
5. Low wear rate.
6. Smooth engaging characteristics.
7. Compatibility with mating surfaces, i.e., minimum galling, wear, or heat checking.
8. Nonfusibility with opposing surface.
9. Noncombustibility.

To compare any friction materials all of the properties listed must be considered.

Mechanical Strength: Strength, particularly high - temperature strength, is often the most critical problem for two reasons:

1. The stresses imposed during use are normally quite high, and a wide range of temperatures is encountered.
2. To obtain sufficient strength within the friction materials, the range of usable constituents is severely restricted and strength is normally obtained by sacrificing desirable friction properties.

Metal-ceramic lining minimizes the strength problem by design as shown in Fig. 1, and by the use of metallic matrix materials. The use of a restraining member minimizes the strength necessary in the friction material and allows the use of materials such as ceramic friction - producing additives which normally weaken the material and cause brittle failure.

The metallic matrix or binder is ideal from a strength standpoint. Since it forms around the ceramic grains and retains these grains in a friction-producing position, its strength is not permanently destroyed by high temperatures as in resin-bonded lining, and it cooperates with the ceramic material so that the high-temperature strength properties of the resulting compositon are superior to the metal alone.

Thermal Shock Resistance: Friction materials, to be considered temperature and thermal shock resistant, must be able to resist:

1. Mean or soaking temperatures without structural change.
2. High localized surface temperatures without permanent deterioration.
3. Repeated high temperature gradients without cracking due to thermal shock or thermal fatigue.

Metal and ceramic materials used in metal-ceramic lining are selected specifically to meet these rigid thermal requirements. No structural change occurs due to mean temperatures obtained during use because the lining is "heat treated" during processing at higher temperatures than the soaking temperatures normally encountered during use.

Although some surface damage may occur due to high localized temperatures, no permanent damage occurs which would jeopardize the future operation of the friction member. In fact, surface changes due to high temperatures normally improve the friction stability and wear properties of the material.

Since the metal is the continuous or bonding phase, the thermal shock properties of metal-ceramic lining are excellent. Surface

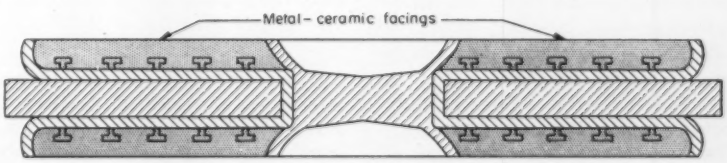


Fig. 1—Typical design for a metal-ceramic friction material mounted in a restraining member.

XUM

cracks occasionally occur in the glaze formed on the surface, but no structural damage or detrimental effect on lining life has ever been attributed to these cracks.

Heat Absorption: High heat-absorbing properties are desirable in a friction material so as to provide a larger heat reservoir to maintain lower temperatures in the friction device. This principle can be applied only to lining which is heat resistant because higher mean lining temperatures will be obtained when using the lining as a heat reservoir.

The heat-absorbing properties of metal-ceramic lining are superior to those of organic bonded lining since the specific heat, specific weight and thermal conductivity are all higher. Conventional metallic facings have similar heat-absorbing properties, but their more limited heat resistance reduces their effectiveness as a heat reservoir.

Coefficient of Friction: A high coefficient of friction is desirable in most lining applications, and a consistent coefficient is essential for good performance in any clutch or brake. A very consistent coefficient of friction with increasing temperatures is produced by proper selection of a ceramic material aided by the heat-resistant properties of metal-ceramic linings. Fade characteristics at high temperatures are superior to any of the conventional organic or powdered-metal lining materials. The curve of coefficient of friction vs. surface temperature, Fig. 2, gives a general comparison between metal-ceramic lining and organic linings. These curves are average values obtained from button tests conducted at Bendix on many best-grade organic materials.

In some applications metal-ceramic lining has been found to have lower friction values at high normal loads (above 150 psi). However, in most of these applications the lower coefficient of friction has been corrected by a change in lining composition.

Although metal-ceramic friction materials tend to have a decreasing coefficient of friction with repeated applications due to a glaze formation on the surface, this problem has been largely eliminated by a development of ceramic materials and additives to control the glaze formation.

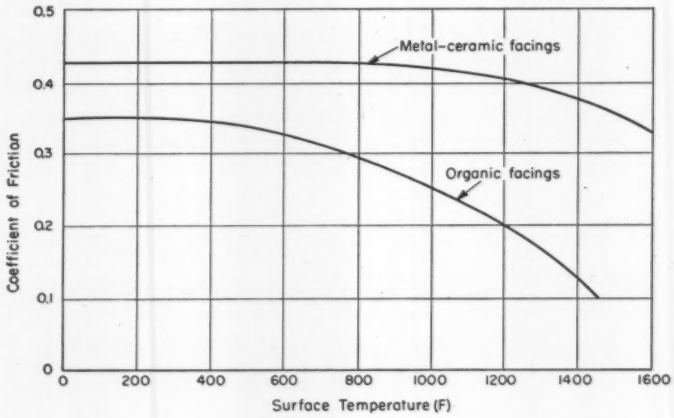


Fig. 2—How coefficient of friction varies with temperature for typical organic and metal-ceramic facings.

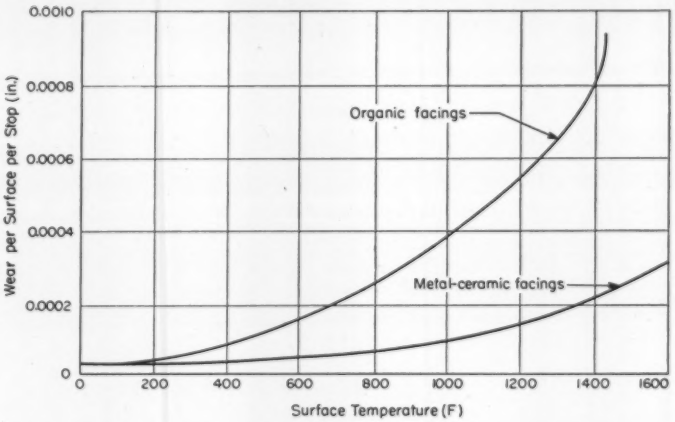


Fig. 3—Variation of wear rates of organic and metal-ceramic facings with changes in temperature.

Wear Rate: Low wear rate, of course, is an essential property of all friction materials. In actual experience with metal-ceramic linings, the wear life has been extended from three to ten times over conventional linings. The good wear characteristics of this lining can be attributed to a number of factors:

1. Superior high - temperature strength property previously discussed.
2. Glaze formation which normally occurs on the surface of the lining.
3. Unique properties of the hard, wear-resistant ceramic particles imbedded in the metallic matrix.

The good, low wear rate obtained with metal-ceramic lining at elevated temperature is compared to a conventional organic lining in Fig. 3. These curves are also average values obtained from testing a number of different linings

on the button tester.

Glaze formation on the surface of the lining affects all of the friction properties, but it is particularly desirable in reducing the wear of the friction article. Control of the glaze composition of properties has been a major factor in developing this type of lining. Compositions have been developed which will promote glaze formation and control its effects on friction properties for most of the conditions encountered in clutches and brakes. The wear rate is also controlled to a large extent by the amount of ceramic material incorporated in the lining.

The use of almost any hard, refractory ceramic material will accomplish the wear reduction mentioned above. However, to obtain the other desirable friction properties, selection of the specific ceramic material is much more critical. The ceramic material and additives used to control the glaze formation, as previously mentioned, can be selected to control torque - velocity characteristics, which have an important bearing on the engaging characteristics. The torque-velocity characteristic of metal-ceramic lining is affected by different operating conditions, but in most cases a uniform torque with decreasing velocity can be obtained by proper selection of lining composition.

Uniformity of torque, particularly near the zero slip velocity, is often very important in the prevention of chatter in the brake or clutch. Where the friction device requires operation to a full zero slip velocity condition, it is usually necessary to have the static and dynamic coefficient of friction as close to the same value as possible. If this is not done, a slip-stick phenomenon may occur to produce squeal and chatter. This condition is particularly troublesome where such resulting torque variations harmonize with the natural frequency of the friction device and its mounting.

Engaging Characteristics: The rigid nature of metal-ceramic lining, particularly at higher temperatures, may promote more aggressive engaging characteristics caused by irregularities at the friction surfaces than will the more resilient organic bonded lining. However, by control of torque characteristics through lining composition and proper design of the friction device, good engaging characteristics have been obtained in many applications of metal-ceramic linings.

Mating Surfaces: Good mating-surface conditions with any lining imply:

1. No galling or transfer of lining material.
2. Minimum and uniform wear.
3. Minimum heat checking due to high surface temperatures.

Galling of the opposing surface, which was initially a problem with metal-ceramic lining, has been largely eliminated by the development of compositions which will glaze at their surface and prevent transfer of the matrix metal to the opposing surface. However, the glaze formed on the surface is hard and, unless used against a similarly hard material, can cause wear of the opposing surface. This wear is normally uniform and progresses at a slow rate, and the advantages obtained by reducing heat checking are often more important than the wear created by metal-ceramic lining. The optimum opposing-surface materials for use with metal-ceramic lining have not definitely been established, but in general high-strength cast iron and hardened steel have been found more desirable than lower-strength materials.

The cup or restraining member used with metal-ceramic lining has caused grooving in some applications. However, proper selection of the cup material and lining composition has minimized this effect so that it is not objectionable in view of the other desirable lining characteristics.

Nonfusing Surfaces: One of the most essential properties of a high-temperature friction material is the complete absence of any tendency to weld or fuse to the opposing surface, regardless of any overload or abusive condition imposed in service. High ceramic content and good heat-resisting properties of metal-ceramic lining preclude this possibility.

From a paper entitled "Cerametallic Friction Material" presented at the SAE National Tractor Meeting in Milwaukee, September, 1956.

Principles of psychological testing in

Selecting Engineering Personnel

By J. M. Parish
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PSYCHOLOGICAL tests prepared by qualified professional psychologists are reliable and deserve high rank in an employee-selection program. On-the-job performance is improved when the supervisor has available, and understands, the test results of each individual he supervises. All supervisors should receive competent instructions in the use of such test results. These tests alone are insufficient basis for selection and assignment of personnel, but, used in proper combination with other factors, they yield gratifying results. Tests only implement; they do not supplant the interview or the weighted application form.

Above all, tests cannot and must not replace the right and responsibility for management to decide whom it will hire. Tests must not be a scapegoat, an instrument for avoiding the responsibility of hiring.

Selecting the Right Test: The right program differs among companies and perhaps even among the component departments of the companies, depending upon the qualities considered to be most important in the given tasks. A test

is good if, through its use, the company is able to pick more "right" men and eliminate more "wrong" ones for the jobs available.

In general, if an organization decides that it is desirable to set up a testing program, and determines what are the chief problems it intends to solve, it will want to try out a number of likely tests to see which will prove most useful. Test consultants, after reviewing the particular needs of the organization, can best suggest the test to be considered.

Applicants are tested by personnel department staff. Completed tests are sent outside the company to psychometricians for scoring. Results are interpreted by psychologists, who then make recommendations regarding selection and placement. This information is returned to the personnel department, through which it becomes available to the departments which might be interested in the services of the applicant.

To be successful, a testing program must be understood and endorsed by many people within a department or company. Supervisors and department heads must be sold on the program.

Training of Supervisors: Understanding the program does not require knowledge of psychology to the extent studied by the professional psychologist. But it is desirable—a necessity, in fact—that supervisors of every level understand sound fundamentals of human relations and motivation. Training of supervisors should include indoctrination in these principles:

1. Objectives of the individual employees and those of the department can be mutually realized through proper courses of action.
2. Ability to produce, or effective know-how, is the major determining factor of success of the individual.
3. Performance is effective only when people have the will to put their potentialities to work.
4. Progress is attained when people have the desire to become better—to improve their services, methods, costs, knowledge, and all other areas of import. Innovation and creativity are essential.
5. Building a more effective organization of workers is a process—it must always be a matter of "becoming."
6. Each individual is different due to his unique combination of natural mental aptitudes and temperamental qualities, in conjunction with his developed habits, attitudes, skills, and knowledge.
7. Each employee has certain natural inclinations.
8. The environment has considerable influence upon his motivations and values. The "climate" which impinges upon the worker in his industrial society thus strongly influences the demands he makes upon his work.
9. Man, by nature, is gregarious or group-minded, as well as individualistic. Most of his basic needs and wants can be realized only through participation in group actions.

Interpreting Test Results: Psychological tests are used to measure the degree of certain human qualities present in a person and are employed as an implement to substantiate or invalidate other indications predicated upon observation, previous performance, or other frames of reference.

It should be emphasized that all practices utilized in original selection of people are directed toward gaining an understanding of the applicant, and are not solely for the purpose of collecting information about him.

Psychological tests are designed to measure the qualities of intelligence, aptitudes, skills, interests, and temperamental make-up of people. These instruments have been carefully constructed, validated, and standardized, in order to assure reasonably valid, reliable, and comparable results. The nature of human qualities and tests as tools of measurement introduce an element of error in measurement, and the results are most properly interpreted when considered in terms of ranges or relative degrees.

Perhaps the most critical matter of all concerns the personnel operating the program. Tests are no better than the personnel interpreting them. Fully qualified psychologists with PhD degrees are rare—it has been estimated that less than 300 psychologists out of 7300 members of the American Psychological Association have specialized in industrial psychology. However, there is no reason why someone with fewer qualifications cannot do a satisfactory job. As a minimum, he should know tests, be familiar with industrial problems, and be able to work with others.

From a paper entitled "Psychological Tests in an Engineering Department" presented at the ASME Petroleum-Mechanical Engineering Conference in Dallas, Texas, September, 1956.

Controlling Induction Motors

with saturable reactors

By P. L. Alger
General Electric Co.
Schenectady, N. Y.

and

Y. H. Ku
University of Pennsylvania
Philadelphia, Pa.

SPEED of an induction motor can be maintained precisely at any desired value by placing saturable reactors in series with the motor windings and holding the direct current in the reactors (and, therefore, the motor voltage) at the appropriate value with a feed-back control circuit. For small changes

HOWELL MOTOR BRIEFS

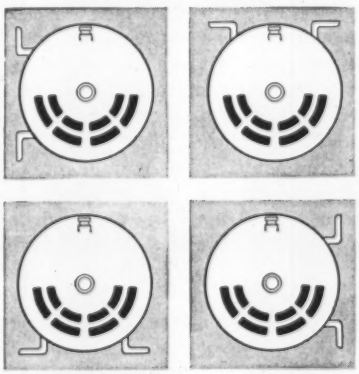
Quick facts for those who apply and specify electric motors

Flexibility of Design Aids Motor Applications

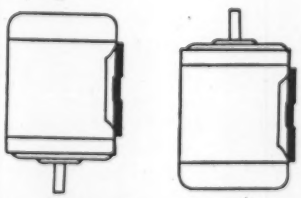
When they originally embarked upon the program of developing the basic Series 100 motor design for the new rerated frame sizes, Howell engineers set goals considerably above and beyond the requirements of the NEMA specifications. Among them, "maximum flexibility" of design was achieved to a degree that is outstanding in the motor industry . . . and that directly benefits machine designers who utilize standard motors.

Involved is not only unusual flexibility of positioning and lead connections, but a ready interchangeability of the five basic enclosure types within each frame size.

DESIGNED FOR MOUNTING IN ANY OF SIX POSITIONS

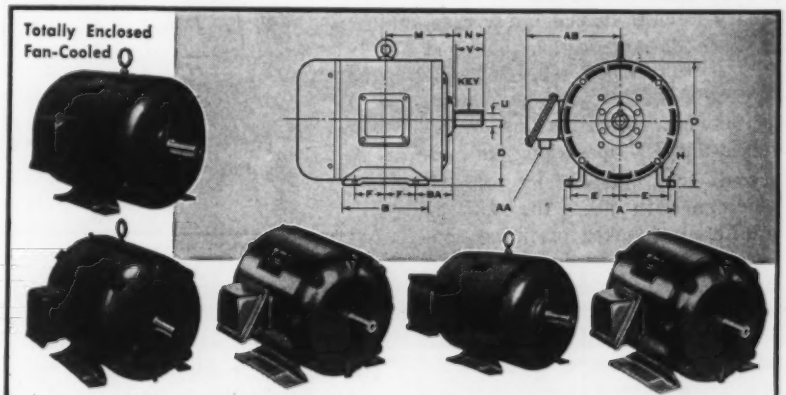


As illustrated by the diagrams above, Howell Series 100 Open Drip-Proof motors can be side-wall or ceiling mounted simply by revolving the end plates. The other four basic enclosure types do not even require this simple change.

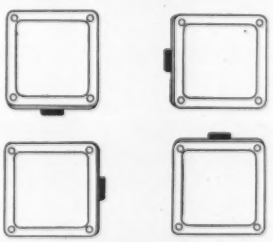


SHAFT DOWN SHAFT UP

Series 100 Totally Enclosed Fan-Cooled motors — in fact all of the five enclosure types — can also be mounted shaft down or shaft up with no modification in design required.

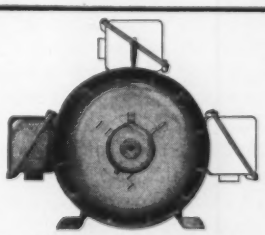


FIVE BASIC SERIES 100 ENCLOSURES HAVE SAME DIAMETERS, SHAFT AND MOUNTING DIMENSIONS — Unlike many other motors, the basic Howell Series 100 enclosures do not vary in diameter (or any of the essential mounting dimensions, except length) from one type to another (except a few 2-pole ratings). This is because of the way Howell accomplishes motor cooling, with "heat source" ventilation ducts in the stator itself . . . not by enlarging Totally Enclosed Fan-Cooled or Explosion-Proof frame diameters. This uniformity simplifies space allocations for the machine designer and allows for interchangeability of enclosure types to meet varying job requirements.



BOX EASILY ROTATED FOR 4-WAY HUB LOCATION

Series 100 conduit boxes are mounted to the frames with 4 screws, accessible for easy rotation of the box so that the integral, threaded nipple takes conduit from any of four directions.



CONDUIT BOX LOCATES TO FIT ANY REQUIREMENTS

For further flexibility, a simple modification can be specified for positioning of the conduit box in any of three positions around Series 100 frames.

GET COMPLETE DETAILS WRITE FOR BULLETIN N-100-R

HOWELL Red Band MOTORS

HOWELL MOTORS

HOWELL ELECTRIC MOTORS COMPANY, HOWELL, MICHIGAN

PRECISION-BUILT MOTORS FOR INDUSTRY SINCE 1915

from full speed, and when the torque required at low speeds is relatively small, squirrel cage motors may be used, with the reactors in the primary circuit. For large changes in speed, and when high torques at low speeds are required, wound-rotor motors with secondary resistors may be used, and the reactors may be placed in either the primary or the secondary circuit. In the latter case, good performance can be obtained over a wide speed range by employing a secondary reactor-resistor network. When braking, or reversed-torque operation, is required, two independent primary windings, with either the same or a different number of poles, controlled by independent reactors, may be used. By combinations of these schemes with contactors to change the connections when needed the speed-torque performance of a direct-current shunt motor can be substantially duplicated, although the induction motor efficiency will usually be lower and its heating greater.

Alternative Methods: If a typical single-winding induction motor with a low-resistance secondary, driving a fan, is connected to the power system through saturable reactors, the speed-torque curves that can be obtained are as shown in Fig. 1. With the reactors fully saturated, the motor torque follows curve *A*, with a high maximum torque and a very small full-load slip. If the external reactance is increased, the maximum torque of the motor falls, and the speed at which maximum torque occurs rises proportionally, so that the speed at full-load torque decreases very little, as shown by curve *B*. When the primary reactance is increased to such a high value that the maximum torque is less than the full load torque, the motor speed falls rapidly, and the motor operates on the unstable side of the torque curve, as shown by curve *C*.

Even though stable operation may be secured with this arrangement, by means of feed-back control, the performance of the motor at low speed will be unsatisfactory, because the reactors required for control are large, the motor power factor is always less than 0.7, and a highly developed circuit is required for accurate control of the speed. For these reasons, applications such as fan drive, which require very small slip at the highest torques, should have the control reactors placed in the secondary circuits.

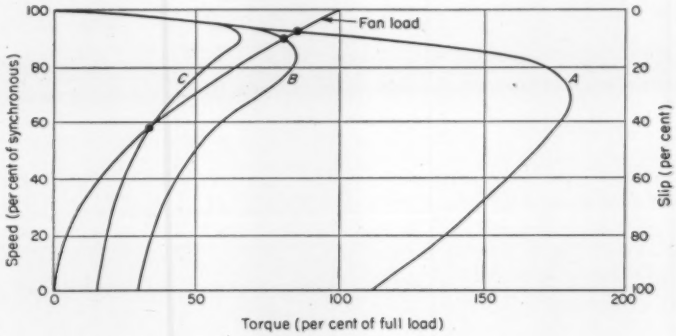


Fig. 1—Speed torque curves for induction motor driving a fan with reactor speed control.

However, for such applications as bridges and hoists, which require high torques at low speeds and braking, and which can permit a slip of 10 per cent or more at full-load torque, the primary reactor control is quite suitable. Of course, the efficiency of the system is always a little less than the ratio of the operating speed to synchronous speed, just as for any wound-rotor motor, so that the scheme is not suitable for applications requiring continuous operation at low speeds, unless the high power losses are permissible.

Summary: By means of Amplistats, feed-back control circuits, and saturable reactors, a standard wound-rotor motor can give adjustable constant-speed performance similar to a Ward Leonard dc drive, over the complete range from +100 to −100 per cent of normal torque. The kva rating of the primary reactors required to give this performance is roughly 80 per cent of the kva rating of the motor. However, differences in normal current densities, temperature rises, and methods of rating for motors and for reactors make an exact statement of the requirements difficult.

The underlying idea in this development is to assemble essentially standard parts, motors, reactors, resistors, etc., to form a speed-control system, instead of using such limited-purpose devices as eddy-current clutches, ac commutator motors, etc. By providing taps on the reactors and resistors, adjustments can readily be made in the field to suit special or changing requirements. And equipment of large size, rated in hundreds of horsepower, may be provided in less time and with less risk than if other methods of obtaining stepless speed control are employed. However, efficiency considerations limit the use of the reactor speed control to applications where the operation is intermittent, or high torque is needed over only a moderate speed range, or where the power losses are not an important characteristic.

A noteworthy feature of the dual-winding reactor speed control is that it provides automatic braking (by "plugging" the motor) to bring the speed down promptly to a desired lower value or to rest without overshoot, as well as providing high accelerating torque to bring the motor promptly to a desired higher speed.

From a paper entitled "Speed Control of Induction Motors Using Saturable Reactors" presented at the AIEE Fall General Meeting in Chicago, October, 1956.

Circle 561 on page 19→

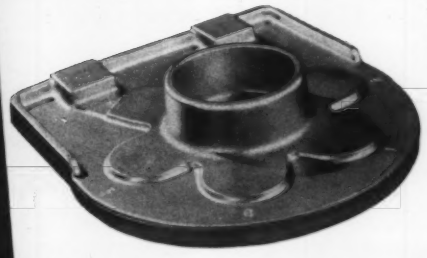
main valve seat for fire plug

Sand-cast pegs bent easily, causing improper fire plug operation. Full line pressure could not be maintained. Machining often uncovered blow-holes causing rejects. Switched to brass forging for higher strength, dense structure, closer tolerances, reduced over-all costs.

quick-acting fuel coupling

To enhance its reputation for quality and to assure tightness under pressure, Ever-Tite Coupling Company turned to forgings for quick couplings used to transfer petroleum and other liquids. Because of the abuse to which this type of equipment is subjected, forgings offer unexcelled performance.

base for TV signal transmission



Porosity and blow-holes in sand-cast part caused "high standing wave," or loss of power feeding into TV transmitting tower through base on end of cable. This required tearing down whole assembly at considerable cost. Switch to dense, strong forging eliminated rejects and power leakage.

water meter lid and register box

Lid converted from sand casting to brass forging. Register box from sand casting to pressure die casting. Weight reduced greatly on both — thus lowering costs. Closer tolerances after change eliminated costly machining on the box.

Vital Change

from sand castings to brass forgings

Titan brass forgings are more easily drilled, tapped, broached and milled than are sand castings. Fewer machining rejects result. Forgings are hot-pressed quickly, are denser, tougher and stronger. Moreover, brass forgings have a smooth beauty and warmth not obtainable in sand castings. Scrap is reduced. Some machining operations necessary on sand castings are actually eliminated by switching to accurate-dimensioned forgings. Getting down to brass tacks, what this means to you is lower costs and a better product by switching to Titan hot-pressed brass forgings.

Send us a sample, drawing, and production quantities of sand-cast assembly parts you now use. We'll quote you on changing to brass forgings.

If you want more data on Titan brass forgings, send coupon below:

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Gentlemen:

- ☐ Will send sand-cast part and details for you to quote as brass forging
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METAL MANUFACTURING COMPANY

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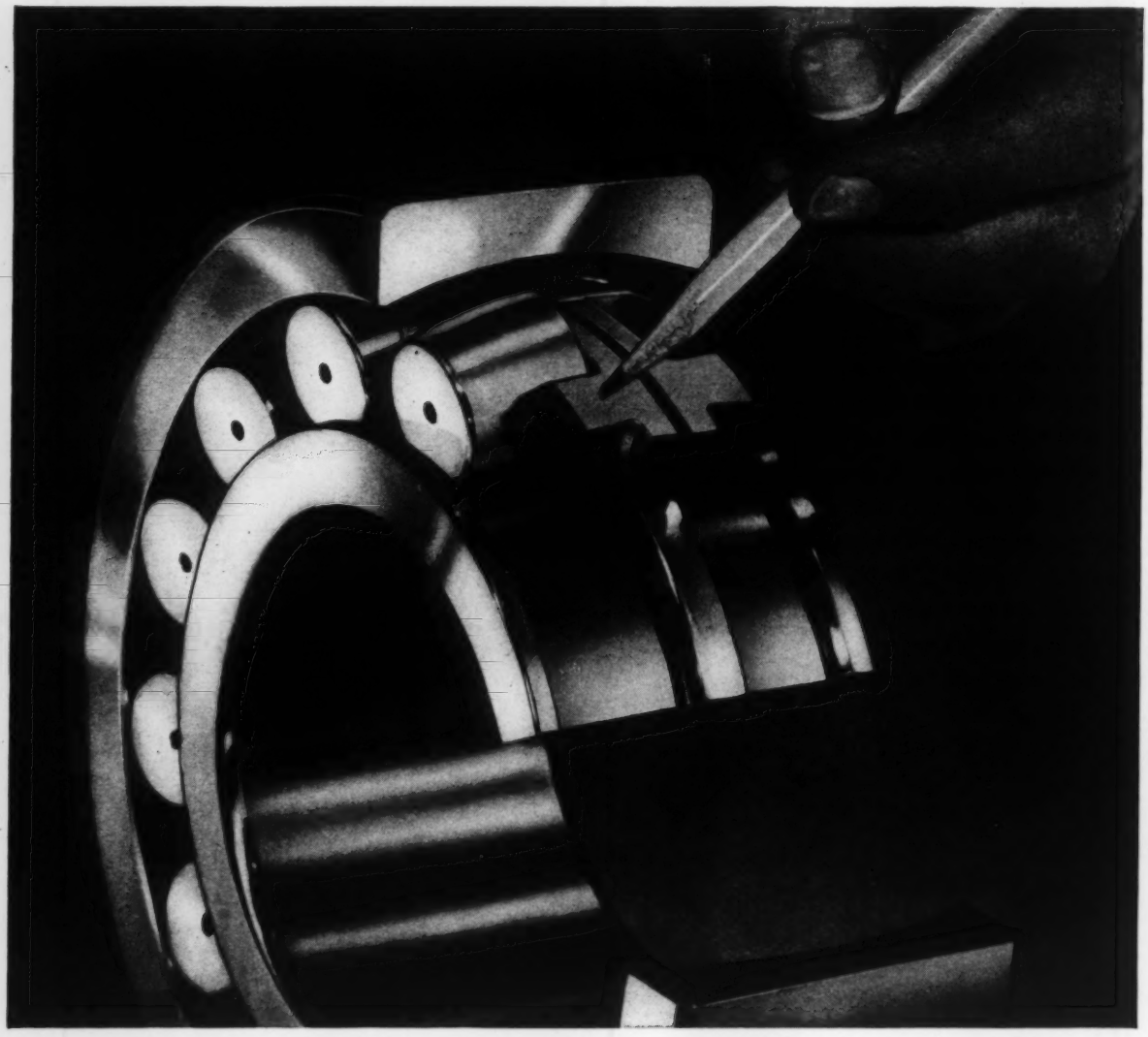
TORRINGTON *SPHERICAL ROLLER* BEARINGS



Land-riding cages for longer life!

These fully machined cast-bronze, land-riding cages—one for each path of rollers—are important performance builders in TORRINGTON'S Spherical Roller Bearings. The one-piece retainers keep the rollers perfectly aligned at all times, even under conditions of shock load and sustained speeds. Lubrication is more effective, too, as the lubricant has easy access to vital points of contact between rollers and races.

This feature is typical of TORRINGTON'S design, made possible through long experience in serving industry with the finest in precision bearings. That's why it pays to look to TORRINGTON first when your application calls for Spherical Roller Bearings. They're available from stock with either straight or tapered bore, for shaft or adapter mounting.

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90th ANNIVERSARY 1865-1955

TORRINGTON BEARINGS

Spherical Roller • Tapered Roller • Cylindrical Roller Needle • Ball • Needle Rollers

Circle 562 on page 19

HELPFUL LITERATURE

for Design Executives

For copies of any literature listed, circle Item Number on Yellow Card—page 19

Checks & Tags

Where, when and how to use metal checks, tags, plates, signs, badges and similar items for identifying products is explained in comprehensive catalog "Checks & Tags by Matthews." Typical types and sizes are shown. Fourteen multi-page bulletins are bound in single book. Jas. H. Matthews & Co.

Circle 401 on page 19

Power Transmission Equipment

Condensed catalog 1200 on power transmission equipment contains design data on nonlubricated flexible couplings, variable speed pulleys, wide variable speed belts and sheaves, variable speed transmissions, adjustable motor bases and universal joints. Sizes and ratings are given. 12 pages. Lovejoy Flexible Coupling Co.

Circle 402 on page 19

Stampings & Drawings

Information that will simplify specifying and ordering stampings and deep drawings is found in illustrated bulletin PM-3. How difficult design problems were solved is shown, along with examples of parts produced. Facilities are outlined. 6 pages. Stanley Works, Stanley Pressed Metal Div.

Circle 403 on page 19

Milling Spindles

Motorized spindles with infinitely variable speed in sizes up to 200 hp and independent drive spindles up to 60 hp are described in illustrated bulletin C15. Use is for milling, boring, routing and drilling. Specifications for these products, plus slides and feeds, are given. 6 pages. Standard Electrical Tool Co.

Circle 404 on page 19

Socket Screws

Complete line of socket head cap screws made of alloy or stainless steels in sizes from No. 4 to 1½ in. and microsizes from No. 0 to 3 is described and illustrated in folder. Also covered are Dryseal pressure plugs and hex socket screw keys. 4 pages. Cleveland Cap Screw Co.

Circle 405 on page 19

Hydraulic Valves

Solenoid controlled and panel mounted hydraulic valves rated at 3000 psi are described in illustrated catalog 261. Features of construction and operation are shown in cut-away views, piston designs, spools, JIC symbols and interchangeability of parts. 8 pages. Rivett Lathe & Grinder, Inc.

Circle 406 on page 19

Centrifugal Fans

Airfoil centrifugal fans for heavy duty industrial applications are detailed in illustrated catalog 4824. Several possible volume control methods are evaluated and brake horsepower curves for four methods are included. Volumes range up to 1 million cfm. 8 pages. American Blower Corp.

Circle 407 on page 19

Contract Manufacturing

Available services for design, development and manufacture of screw machine products and cold upset parts are outlined in folder. Diverse types of products made are shown. Listed are secondary operations available and machine capacities. 4 pages. Chicago Screw Co.

Circle 408 on page 19

Electrical Tapes

Scotch electrical tapes for motor construction and repair are subject of illustrated catalog E-MCB. Properties of various tapes and typical applications are detailed. They have standard and thermosetting types of pressure-sensitive adhesives. 12 pages. Minnesota Mining & Mfg. Co.

Circle 409 on page 19

Recording Oscillograph

Precise means of recording static or dynamic data is provided by the type 5-114 recording oscillograph, illustrated in descriptive bulletin 1500D. Its features, applications, specifications and accessories are detailed. Supplement gives prices. 16 pages. Consolidated Electrodynamics Corp.

Circle 410 on page 19

Roller Chain & Sprockets

Stock drives, drive chain, conveyor chain, installation and maintenance, lubrication, sprocket wheels, casings and chain tighteners are but a few of the subjects covered in Manual No. 2457 on precision steel roller chain and sprocket wheels. Data to aid in designing drives are presented. 148 pages. Link-Belt Co.

Circle 411 on page 19

Clutches & Transmissions

Illustrations and brief descriptions of a variety of automatic clutches and transmissions are included in bulletin 56-D-1. Clutches are for use on ¾ to 3½, 4 to 8½ and 10 to 25-hp gasoline engines. Transmissions are for use on 1 to 20-hp engines. 4 pages. Salsbury Corp.

Circle 412 on page 19

Glass-to-Metal Seals

"Steels for Glass-To-Metal Seals" is title of technical manual on five steels which are utilized for application and design of glass-to-metal seals. Seals are used in headlights, electronic tubes and other equipment. 4 pages. Allegheny Ludlum Steel Corp.

Circle 413 on page 19

Instruments & Components

Catalog C-703 introduces such new Berkeley instruments and components as Ferristors, decimal counters, time interval meters, nuclear scalers, and nuclear automatic sample counters; computers and computer-quality control system components; and systems for data reduction, handling and logging. 8 pages. Beckman Instruments Inc., Berkeley Div.

Circle 414 on page 19

Drawn Welded Tubing

Sizes ranging from 0.0625 to 2.5-in. OD are available in Weldrawn tubing in nine types of stainless steels, Monel, Hastelloy C. Nichrome V, beryllium copper, Constan, nickel irons and unalloyed titanium. Analyses, tolerances and design data are given in Memorandum No. 2. 3 pages. Superior Tube Co.

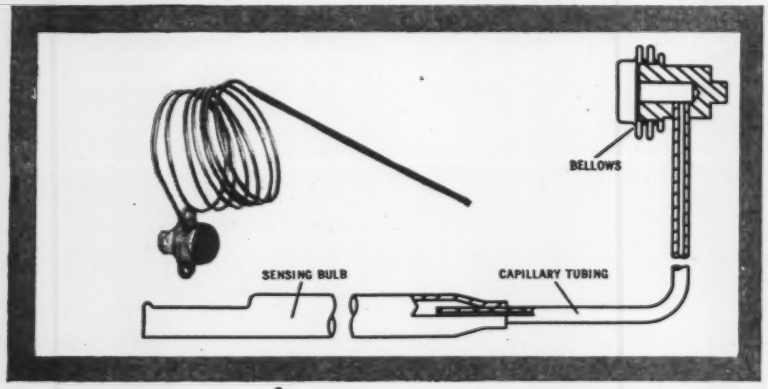
Circle 415 on page 19

Totally-Enclosed Motors

Design and performance information on ½ to 30-hp NEMA rerated and ½ to 100-hp nonrerated totally-enclosed, fan-cooled alternating current motors is given in illustrated

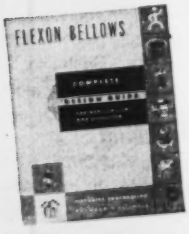
FLEXON® BELLOWS *Design Briefs*

How to Get the Best Performance at Low Cost with Temperature Sensitive Devices



FLEXON OFFERS THE COMPLETE BELLOWS SERVICE

Flexonics Corporation manufactures a complete range of bellows and bellows assemblies in brass, bronze or stainless steel for vacuum equipment, thermostatic devices, pressure controls, packless valves, pneumatic instruments, hydraulic mechanisms, rotating shaft seals and many other services.



The Flexon Bellows Design Guide gives valuable application and design information. Write for your copy, today.

Cost-engineered FLEXON Bellows Assemblies are the answer to your need for high quality performance in temperature controls.

FLEXON Bellows Assemblies used in this type of application consist of a bellows, capillary tube and sensing bulb, completely filled with a suitable liquid. Expansion and contraction of the liquid with temperature changes is converted to bellows motion. This provides small increments of motion for a given temperature range making it possible to accurately regulate temperature by modulating the heat source.

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FORMERLY CHICAGO METAL HOSE CORPORATION

Manufacturers of flexible metal hose and conduit, expansion joints, metallic bellows and assemblies of these components.

In Canada: Flexonics Corporation of Canada, Ltd., Brampton, Ontario

Helpful Literature

bulletin 51B7225D. Included are cutaway views, tables of ratings and dimensions, and a horsepower frame chart. 6 pages. Allis-Chalmers Mfg. Co.

Circle 416 on page 19

Resistance Welding

How accurate control in resistance welding assures optimum product performance is explained in illustrated bulletin 338 entitled, "At Last . . . Absolute Accuracy in Welding Control." 8 pages. Sciaky Bros., Inc.

Circle 417 on page 19

Filtering Equipment

Olson liquid filters with capacities of 1000 to 10,000 gph of solvents and Delpark full-flow self-cleaning continuous automatic coolant filters are subjects of two illustrated bulletins. 4 pages each. Industrial Filtration Co.

Circle 418 on page 19

Electron Tube Sockets

Technical data sheet 50A gives design and application information on new series 1550 type B Duodecal electron tube socket for electronic equipment. 2 pages. DeJur-Amsco Corp.

Circle 419 on page 19

Static Control Elements

Fundamentals and features of general purpose static control elements are detailed in illustrated bulletin GEA-6578. And, or, not, memory and time delay types are detailed. Components and system features are described and the logic function is covered. 8 pages. General Electric Co.

Circle 420 on page 19

Instrument Tubing

Single and multiple instrument tubing products which bend without distortion are described in bulletin 456. Specifications are given for metal, plastic lined and plastic tubing, multiple tube harnesses and tubing ribbons. 4 pages. Samuel Moore & Co., Dekoron Products Div.

Circle 421 on page 19

Universal Joints

Dimensions as well as torque loads and critical speeds of Almetal universal joints for industrial applications are given in illustrated catalog. Splined, keyed, hub and flange yokes and bearing hanger stub shafts are described. Continuous duty ratings

Circle 563 on page 19

AVAILABLE NOW

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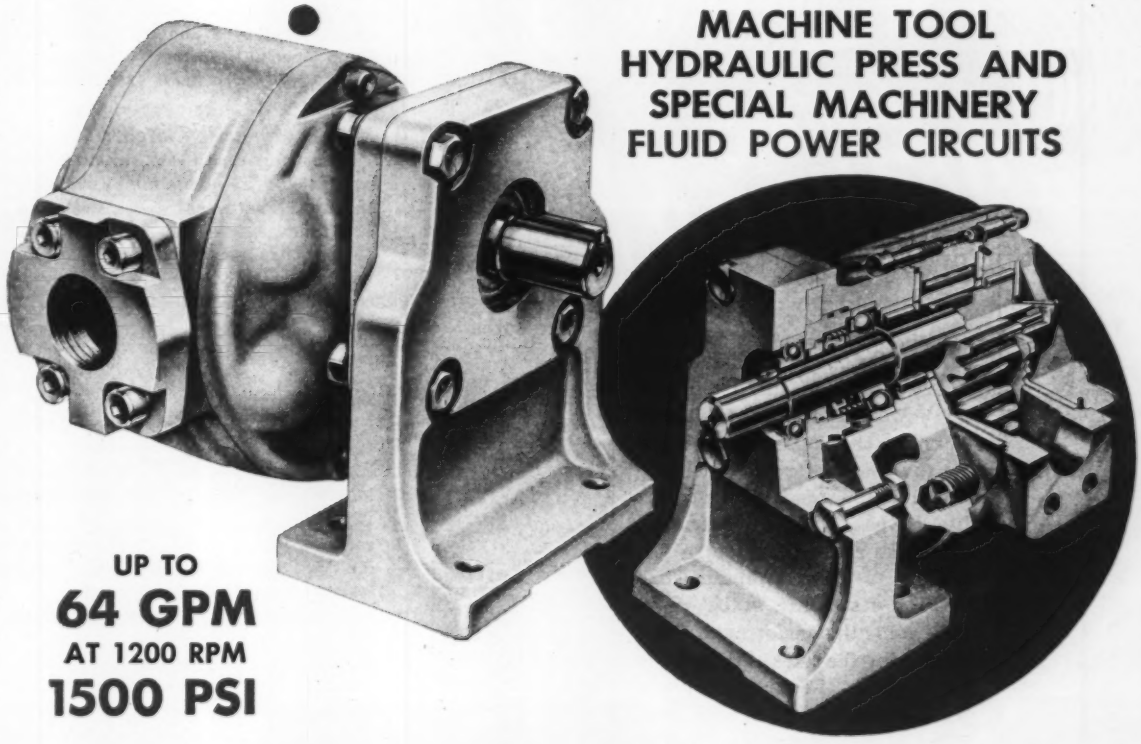
GEAR PUMPS

WITH INDUSTRIAL MOUNTINGS

FOR

MACHINE TOOL
HYDRAULIC PRESS AND
SPECIAL MACHINERY
FLUID POWER CIRCUITS



UP TO
64 GPM
AT 1200 RPM
1500 PSI

HYDRECO Gear Pumps, for years, have been specified as standard Fluid Power equipment by the *big names* in Construction, Earth Moving and Materials Handling Equipment. On these rugged-service applications HYDRECO Gear Pumps perform with outstanding dependability. They will operate under conditions of pressure, temperature, and speed unheard of on the usual industrial application. Mobile Equipment is a highly competitive field and HYDRECO Pumps have always afforded design engineers substantial economies in original equipment costs!

HYDRECO Gear Pumps are now available with standard industrial mountings, port connections and shafts. Builders and users of Machine Tools, Presses, and Industrial Equipment can now profit by the economies in these Pumps.

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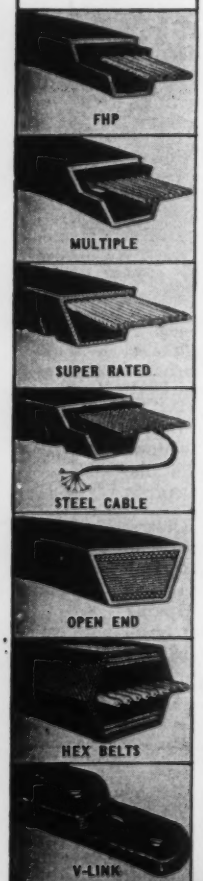
Circle 564 on page 19

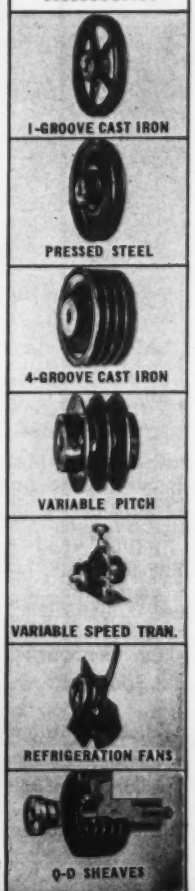
Mor-Grip v-belts



Maurey *engineers* v-drives for every situation; the "stop and go" spurts of refrigeration drives; the pulsating, high torque loads of rock crushing; the smooth, steady-pull of textile drives... for short centers, and wide range of speed ratios. Maurey V-drive equipment has proved its value since 1917, improving the performance, and increasing the sales of thousands of products. Maurey delivers pulleys, belts and accessories *quickly* from complete stocks. Whether you are designing a new v-drive or improving an old one, contact Maurey. Call your local Maurey Distributor, or write direct.

Request These Catalogs

Pulleys, Sheaves V-Drive Accessories



maurey manufacturing corp.

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Helpful Literature

range up to 12.1 hp per 100 rpm. 8 pages. Detroit Bevel Gear Co.

Circle 422 on page 19

Rotary Cam Limit Switch

Bulletin 1600B is descriptive of the Danly rotary cam limit switch for mechanical presses. Readily adjusted for timing of press controls or of auxiliary equipment synchronized to the press cycle, control is rated 10 amp on 115 v. 8 pages. Danly Machine Specialities, Inc.

Circle 423 on page 19

Midget Magnetic Clutches

Measuring 1 5/16 in. in diameter by 2 45/64 in. long, miniature precision magnetic clutches develop a static torque of 9 lb-in. with a 3 w power consumption when operated on 110 v dc. Full details are given in bulletin "Magnetic Clutches." 4 pages. Dial Products Co.

Circle 424 on page 19

Magnesium Alloys

Both the former and the newly Dow-adopted ASTM designations for Dow magnesium alloys are listed on handy wall chart or data file sheet. Designations cover mill products, sand and permanent mold castings, die castings and ingots. Dow Chemical Co.

Circle 425 on page 19

Nylon Bobbins & Washers

Maximum and minimum wall thicknesses, core lengths and sizes, and flange sizes of nylon bobbins and dimensions of nylon washers for electrical uses are tabulated in bulletin BW 756. Sample bobbins and washers will be sent with catalog. 4 pages. Cosmo Plastics Co.

Circle 426 on page 19

Signal Generators & Controls

Details of the new signal generator and control system developed to meet the varied requirements of a signal source for electrical, electroacoustical and acoustical measurements are given in illustrated folder. 8 pages. Brush Electronics Co.

Circle 427 on page 19

Steel Pipe, Tube & Fittings

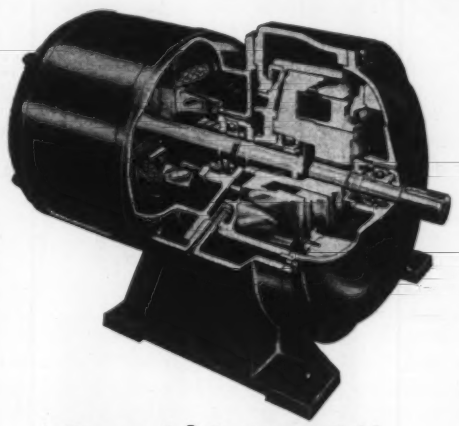
Condensed data on mechanical properties, creep strength, physical properties, hot and cold bending, welding, heat treatment and working pressure of Croloy 2¼ steel pipe, tubing and welding fittings are con-

No Commutators, No Rings, No Brushes, No Rotating Coils—in the NEW

EATON

DYNAMATIC®

Adjustable Speed Drives



Dynaspede® Stationary Field Coupling, with Integral Motor

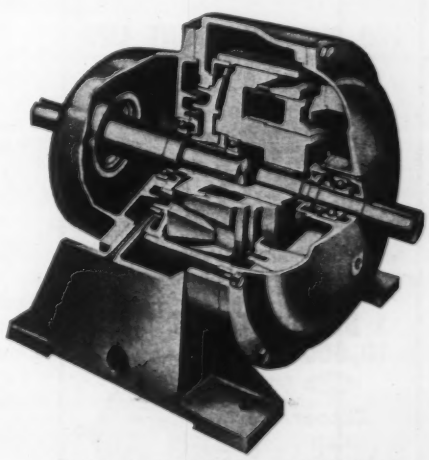
Dynamatic stationary field couplings are the simplest drives so far devised to provide infinitely adjustable speed from an alternating current source. The absence of rotating coils, brushes, slip rings, and commutators in this design holds wear and maintenance to an absolute minimum. Dynamatic electronic or magnetic amplifier controls, in combination with these drives, provide wide latitude in operating functions.

Check these Outstanding Advantages:

Accurate speed control • Wide speed range • Low power losses • Simple construction • Rapid response • Remote control • Quiet, efficient operation • Low maintenance costs

Ajusto-Spede® Drives: Air cooled, stationary field eddy-current couplings mounted integrally with D-flange open drip proof squirrel cage motors are available in capacities from 1 to 75 HP. Units of the same design and capacities are also available without motors.

Dynaspede® Drives: Liquid cooled, stationary field couplings mounted integrally with D-flange squirrel cage motors are available in capacities from 3 to 75 HP. Motor types available are drip proof, splash proof, totally enclosed fan cooled, and explosion proof. The coupling is totally enclosed. Separately mounted couplings are also available in capacities from 3 to 2500 HP and larger.



Stationary Field Coupling for use with Separately Mounted Motor

Send for Detailed Information on these New Stationary Field Couplings and Drives

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The proven answer for office machines, amusement machines, and factory equipment where service is moderate.

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Millions used for vending machines and other equipment where space is limited.

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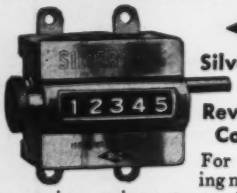

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Silver King Revolution Counter

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10,000 CPM

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Clipper Coil Winding Counter

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See your PIC Representative or write.

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Circle 567 on page 19

Helpful Literature

tained in bulletin 145-A. Material is suited for service up to 1175° F in nominal pipe sizes up to 9⅝ in. 4 pages. Babcock & Wilcox Co., Tubular Products Div.

Circle 428 on page 19

Motor Selector Chart

Binder-size selector chart tabulates characteristics and performance ranges of all fractional horsepower motor types. Speed-torque curves for basic units are illustrated. Howard Industries, Inc.

Circle 429 on page 19

Welding Fittings & Flanges

Dimensional data on Tube-Turn wrought iron welding fittings and flanges are contained in illustrated folder. Sizes range from ½ to 12 in. Physical properties and typical applications are discussed and illustrated. National Cylinder Gas Co., Tube Turns Div.

Circle 430 on page 19

Wire Rope

Diverse applications for wire rope shown in illustrated bulletin 5647 are helicopter, water well drilling, sling lift, water tower dismantling and elevators. Swaged fittings are also covered. 4 pages. Macwhyte Co.

Circle 431 on page 19

Multipurpose Fasteners

Vibrex fasteners which combine features of quick-release closures and vibration dampers are described and illustrated in brochure. Their tensile strength, sealing and antivibration characteristics are covered. Vibrex Fastener Corp.

Circle 432 on page 19

Motors & Collector Rings

Torque motors, special motors and collector rings for completing electrical circuits between stationary and rotating parts are subject of bulletin BAW-56. Continuous motor stall characteristics are described, as are eight collector ring sizes. 8 pages. B. A. Wesche Electric Co.

Circle 433 on page 19

Lubricating Equipment

Oil cups and gages, oiling systems, dispensers, valves and chain oilers are described and illustrated in catalog No. 10. Specifications of each unit, application data and typical installations are covered. 32 pages. Oil-Rite Corp.

Circle 434 on page 19

KARAK

Non-metallic material or parts for manufacturing your product. "KARAK" is manufactured in various combinations of graphite and carbon. To suit your requirements any combination of these materials can be impregnated. Bearings - rings - molds and cores - seals for liquids - air and grease pumps - Diesel engines - air compressors, etc., represent only a partial list of applications. Day by day many needs are developing in industry where this type of material is found to be superior to materials now being used.

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Basic Manufacturers

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Circle 568 on page 19

EQUIP YOUR POWER PRESSES AND OTHER METALWORKING MACHINERY WITH THESE FAWICK UNITS FOR . . .

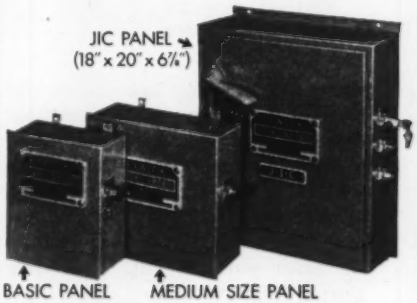
accurate, high speed clutch control

FAWICK TIMING ROTORSEALS

- combination rotary air seal and cycle-timing device for machinery equipped with air-operated clutch and brake mounted on crankshaft
- new, 3-cam, 3-breaker-point design for more accurate control and complete operator safety . . . up to speeds of 500 rpm
- simple cam adjustment through 360° cycle
- completely sealed, self-contained unit
- adaptable to new or existing equipment, easy to install and service, requires minimum shaft space

CAM LIMIT SWITCHES

- accurate 3-cam, cycle-timing device for machinery where clutch and brake are not mounted on crankshaft
- incorporates all important advantageous features of Fawick Timing Rotorseal described above—but does not provide air passage
- chain-and-sprocket link to crankshaft



HIGH SPEED CLUTCH CONTROLS

- for safe and precise control of machinery at increased operating speed
- three sizes—all of NEMA 12 construction with non-repeat protection
- inching, single stroke and continuous operation standard for all control panels. Also includes functions of either "long" or "short" operation, with optional "hand-foot" and semi-continuous operations.
- timed inching relay and size one non-reversing motor starter are available as optional features for medium size and JIC panels. Other panels with features such as larger motor starter can also be furnished.

High-Speed Clutch Controls and either Timing Rotorseal or Cam Limit Switch are components of FAWICK STANDARDIZED PRESS APPLICATIONS, complete package units for low-cost modernization of presses from 15 to 120 tons. For additional information on these and other FAWICK products, contact your nearest FAWICK Representative or the Home Office today.

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FAWICK Airflex
INDUSTRIAL CLUTCHES AND BRAKES

Circle 569 on page 19

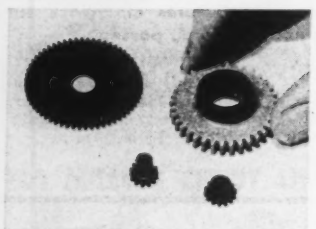
New Parts and Materials

Use Yellow Card, page 19, to obtain more information

Nylon Powder

for wear-resistant, accurate parts

Formulation of finely divided nylon powders, designated Nylasint 64, has high modulus of elasticity and low deformation under load in cold-pressed and sintered form. Material provides high wear resistance, low surface friction, and low hygroscopic and thermal expansion. Parts such as gears, bearings, cams, and wear parts made from the material by cold pressing and oil sintering have uniform



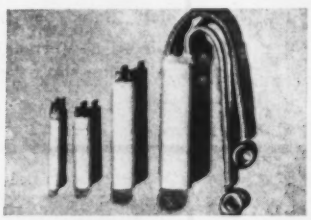
shrinkage and accurate dimensional characteristics. Various inert fillers such as molybdenum disulphide and graphite may be added for specific requirements. **National Polymer Products Inc.**, Reading, Pa.

Circle 451 on page 19

Heating Cartridges

provide stabilized ambient temperatures

Ceramic - body heating cartridges offer selection of body length and diameter to provide units as small as 5/32-in. diam by 1 in. long. Wattage ratings are available to provide densities up to 50 watts per sq in. Design allows wide selection of terminal configurations. Heating elements are just beneath surface to provide fast heating, high heat density, and minimum heat loss to the core. Ceramic, solidly packed with magnesium oxide, is



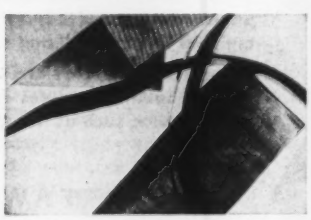
moisture resistant. Cartridges are for use in applications requiring stabilized ambient temperature ranges. **Hotwatt,** 16 Gould St., Danvers, Mass.

Circle 452 on page 19

Glass Fabrics

have low flow under heat and pressure

Teflon-coated glass fabrics, tapes and laminates for use in aircraft and industrial applications have excellent heat resistance, high mechanical strength and extreme toughness. Chemically inert, the fabrics exhibit low flow under heat and pressure, excellent electrical



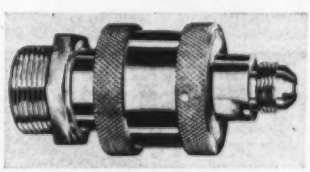
properties over a wide range of temperatures and frequencies, and good strength and resistance to abrasion. They remain pliable at temperatures lower than −100 F and are inert to 390 F. Simple forming is easily accomplished. More complicated structures can be formed at approximately 700 F and 1000 psi pressure. Fabrics are available in standard single ply or multiple-ply laminates, and can be treated on one side only for adhesion to a variety of materials. **Shamban Engineering Co.**, 11617 W. Jefferson Blvd., Culver City, Calif.

Circle 453 on page 19

Self-Sealing Coupling

for hydraulic lines up to 3000 psi

Aircraft self-sealing coupling has quick, positive connection and disconnection with no fluid loss or air inclusion for use on hydraulic systems with temperatures up to 275 F and pressures to 3000 psi. Coupling replaces two shut-off valves and is suited for applications



where hydraulic line must be broken for maintenance, testing, or connection of accessories. Visual or touch inspection determines whether or not coupling is locked. Connection is by manual quarter-turn of union nut; disconnection by axial pull on nut. **Aeroquip Corp.**, Aircraft Sales Dept., Jackson, Mich.

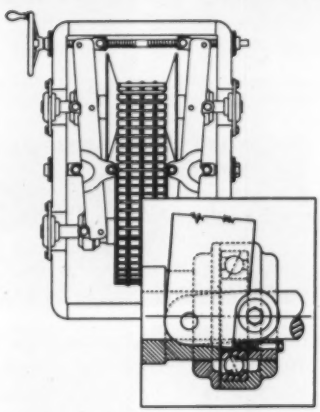
Circle 454 on page 19

Bondable Fluorocarbons

surface treatment allows selective bonding

Teflon and Rulon film, rods, sheets, and extruded or molded shapes are surface-treated to enable these nonadhesive substances

"Only LEWELLEN V/S TRANSMISSIONS give precision ratios"



Internals of Lewellen V/S Transmissions are mechanically connected and symmetrically positioned. All motions are exactly proportioned and accurately adjustable. V/S Belt tracks in true alignment at precise pitch ratios, with controlled tension for full traction throughout the speed range. Infinitely, accurately variable speeds are designed and built into Lewellen V/S Transmissions.

The builder of Lamb-Grays High-Speed Precision Cutter says, "Only Lewellen V/S Transmission gives the precision ratios we require, at the extreme variations in torque resulting from rapid accelerations of the cutter."

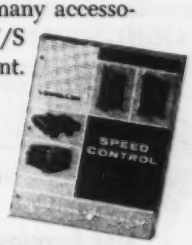
The Lewellen variably drives the rotary shear. Speeds are remotely controlled for a wide range of selected sheet lengths.

Recurring peak loading at the cut, rapid accelerating loads at frequent starts, and 24 hour service are exacting requirements.

The uniform lengths of the stacked sheets is indisputable evidence of Lewellen accuracy.

Lewellen V/S Transmissions offer convenience as well as utility. Lewellens operate at the speeds that machines run. Directly connect machine sections—or, motorized, variably power the machine.

Four standard models—selective controls—many accessories—any driving arrangement . . . Lewellen V/S Transmissions adapt readily to any equipment.



WRITE FOR CATALOG NO. 65

LEWELLEN MANUFACTURING CO. COLUMBUS, INDIANA

Distributors In All Industrial Areas • In Canada—Peerless Engineering Sales Ltd., Toronto-Montreal

Circle 570 on page 19

XUM

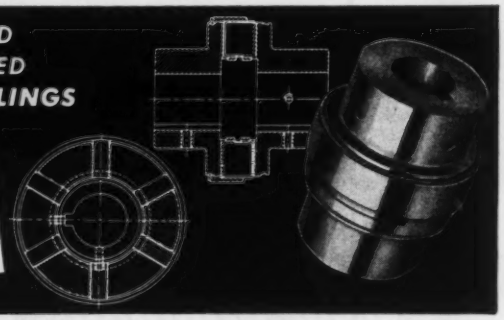
LOVEJOY

Power Transmission Equipment

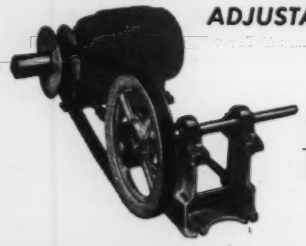
Job-Rated for the Particular Load to Give Maximum Performance on Your Job

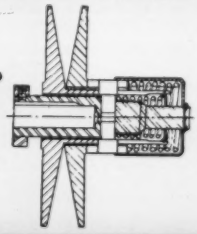
NON-LUBRICATED
EASILY-ASSEMBLED
FLEXIBLE COUPLINGS

Bores (max.) .....¾" to 9½"
O.D. .....⅝" to 21½"
Wt. .....½ oz. to 1500 lb.
H.P. .....1/20 to 3000
Torque (static)..1½ to 5100 ft.-lbs.



MAINTENANCE-FREE INSTANTLY-
ADJUSTABLE VARIABLE SPEED PULLEYS

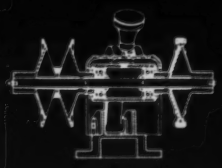


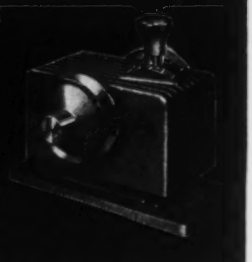


Bores (max.) .....½" to 1⅛"
O.D. .....3" to 13⅜"
Belt Sizes.....A to 2¾ TW
Speed Ratios.....1-1 to 8-1
H.P. (1750 rpm.).....¼ to 15

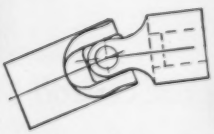
ECONOMICALLY-PRICED INFINITELY-
VARIABLE SELECT-O-SPEED
TRANSMISSIONS

Controls . Lever or Hand Wheel
Belt Sizes.....A to C
Speed Ratios.....1-1 to 10-1
H.P. (1750 rpm.)...½ to 7½





LIGHT-WEIGHT PRECISION-BUILT UNIVERSAL JOINTS



Bores.....¼" to 2"
Hub Dia.....½" to 4"
Static Torque
340 to 130700 in.-lbs.
H.P. (100 rpm.).....½ to 207

Get Lovejoy performance for your equipment.
Request full information now.

LOVEJOY FLEXIBLE COUPLING CO.

4818 WEST LAKE STREET • CHICAGO 44, ILLINOIS

New Parts

to bond with other materials. Essentially a surface treatment, penetration of material is 0.001 to 0.003-in. Either part or all of surface can be treated; balance will retain its nonadhesive properties. Flat shapes can be treated on one side or on both sides as required. Suitable adhesives permit firm bonding of Teflon and Rulon to such materials as wood, metals, cloth, belting, and other plastics. Among applications is bonding of thin sheets (0.003 to 0.065-in.) of fluorocarbon to an inexpensive metal base to achieve same results as solid fluorocarbon alone. **Dixon Corp.**, Bristol, R. I.

Circle 455 on page 19

Silicon Rectifier

miniature unit has rating to 600 v

Silicon rectifier stack is designed for power applications requiring miniaturization, reliability, high efficiency, and operation at high ambient temperature. Rectifier is available in all circuit types with

inverse rms voltage ratings from 70 to 600 v and dc output currents to 4.5 amp at 75 C ambient temperature. Stacks may be arranged in series or parallel to increase voltage or current ratings. Hermetic sealing insures freedom from contamination. Junction diodes are mounted on copper cooling fins and then stacked conventionally, **International Rectifier Corp.**, 1521 E. Grand Ave., El Segundo, Calif.

Circle 456 on page 19

Cap Nuts

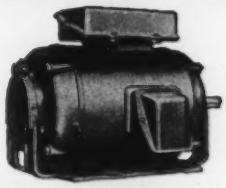
self-locking units for decorative applications

Through-tapped cap nuts are for use on outdoor and indoor steel and aluminum furniture, appliances, plumbing fixtures and other decorative applications where it is

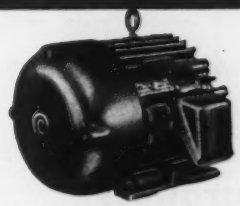
DRIP PROOF—1/20 to 3/4 H.P.
A.C., Single or Polyphase
Send for Bulletin 1-1P1

Let Century Motors help you design top performance into your product...

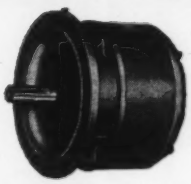
RIGID BASE, OPEN TYPE, PROTECTED
1 to 400 H.P.—A.C., Single or Polyphase
May be used in place of splash proof... screens available for rodent protection.
Send for Bulletin 6-1P1



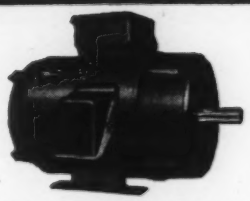
CUSHION BASE, OPEN TYPE, PROTECTED—1/20 to 5 H.P.
A.C., Single or Polyphase
Send for Bulletin 6-1P1



TOTALLY ENCLOSED FAN COOLED
1 to 100 H.P., A.C., Single or Polyphase
Send for Bulletin 6-1P1

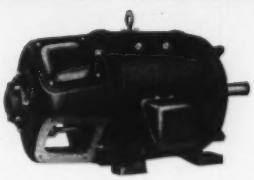


FLANGE BRACKET (NEMA "D")
Round, short frame—for horizontal or vertical operation
Send for Bulletin 6-1P1



FACE TYPE BRACKET (NEMA "C")
With feet for motor-mounted equipment
Send for Bulletin 6-1P1

EXPLOSION PROOF MOTORS
2 to 100 H.P.
UL approval Class I, "C" and "D"
Class II, "E," "F" and "G"
Send for Bulletin 6-1P45

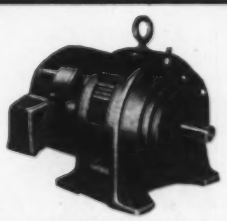


SELECTIVE SPEED DRIVES
1/8 to 150 H.P.
Operate from A.C.; broad range of automatic, stepless speed control; respond to wide variety of remote control devices.

They're Performance-Rated© **to guide you in selecting precisely the right motor size, speed, torque, mounting and frame characteristics for each specific application. Call or write your nearby Century District Sales Office or Authorized Distributor.**

Performance-Rated© **MOTORS**
1/20 to 400 H.P.

Mail this coupon for FREE bulletins



GEAR MOTORS—1 to 125 H.P. (parallel)
⅛ to 3 H.P. (right angle or parallel)
A.C. or D.C., Speed to fit your need.
Send for Bulletin

CENTURY ELECTRIC COMPANY

1806 Pine St., St. Louis 3, Mo. • *Offices and Stock Points in Principal Cities*

To CENTURY ELECTRIC COMPANY, 1806 Pine Street, St. Louis 3, Mo.

Please send me the following bulletins:

(fill in numbers here) .....

.....

.....

Name.....*Title*.....

Company.....

Address.....

City.....*Zone*.....*State*..... CE-91

Circle 572 on page 19

NEW CONTROLLER LINE ADAPTS 576 WAYS

Fenwal Announces Low-Cost Temperature Indicating Controllers

ASHLAND, MASS. — Fenwal Inc., has announced here that tailor-made, accurate, low-cost temperature indicating controllers are now available from stock.

Tailor-mades from stock are made possible by the development of the new Fenwal Series 541 line. The Series 541 is a standardized line of matched temperature indicating controller parts which can be combined easily in 576 ways.

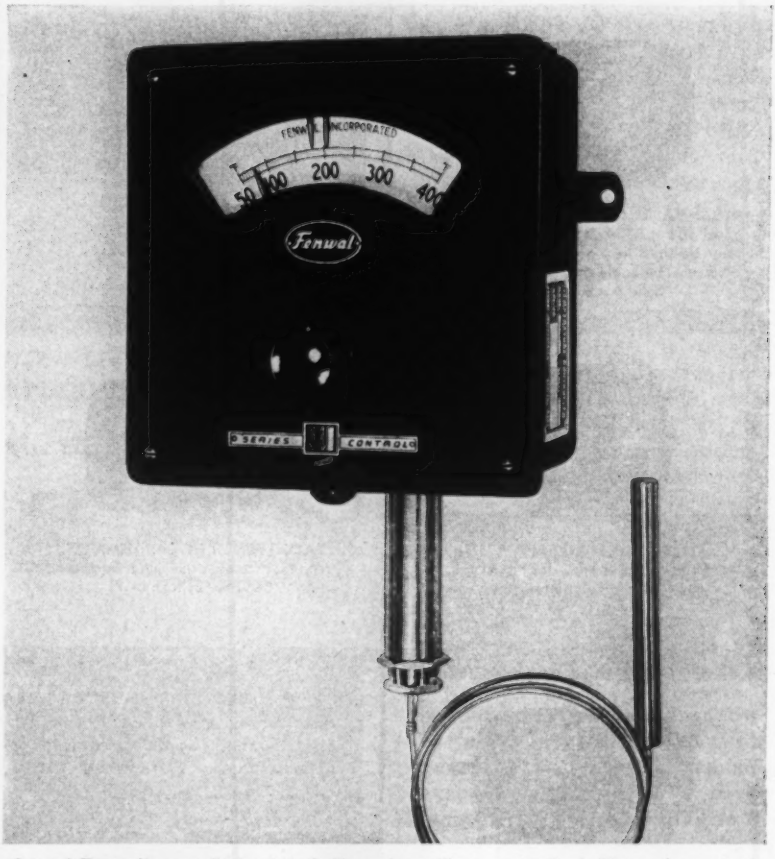
From these possible combinations come perfect solutions to countless temperature control problems. A prospective user lists the characteristics of the ideal temperature indicating controller for his particular operation, and Fenwal assembles an instrument with those characteristics from parts in stock.

No matter what combination is chosen, the result is a rugged, accurate, compact and easily maintained unit in a shock-proof, splash-proof, dust-proof housing. The housing is available in colors to match any equipment in which it may be installed.

Installation and calibration are so simple that instrument technicians and laboratory procedures are unnecessary. And, after installation, all normal temperature adjustments are external.

No matter what combination is chosen, the resulting instrument is accurate to within one per cent of scale. The accuracy is long lasting, with few moving parts and no internal gears. Simplicity of design brings the wear factor close to zero.

Series 541 offers single or double circuit control. There is a choice of four different long-life snap switches, with ratings up to 20 amps, 250 volts, A.C. These switches, singly or in combination, can provide a wide variety of operating characteristics.



One of Fenwal's new Series 541, bulb-and-capillary controllers. Photo shows dual circuit model which has two snap switches, each with a setpoint indicator, that actuate two separate circuits at the pre-set temperatures.

Three stainless steel bulb types are available at no increase in price to meet space or process requirements. Capillaries and bulbs are corrosion-proof. Capillaries are swivel-mounted to protect them from breakage.

There is a choice of three temperature ranges: −150° to 200°F, 50° to 400°F, or 50° to 700°F, or their centigrade equivalents. Special ranges are available on request.

The control mechanism may be subjected to temperatures up to 150°F, and is ambient compensated from 50° to 150°F.

Write to Fenwal Incorporated, 1911 Pleasant Street, Ashland, Mass. Describe the tailor-made temperature indicating controller that would fit your operation perfectly. Chances are excellent that the tailor-made can be yours — at savings never before possible.

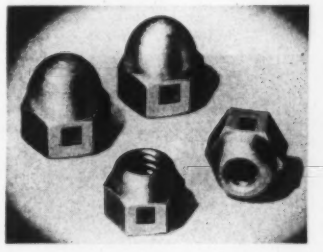
Fenwal

CONTROLS TEMPERATURE ... *PRECISELY*

Circle 573 on page 19

New Parts

impossible to seat a regular cap nut. Self-locking feature of cap nut eliminates need for washer, thereby speeding assembly. Reusable nut utilizes a tough resilient pellet of permanently imbedded

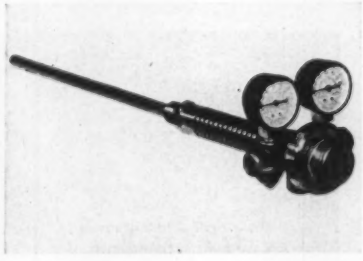


nylon. Pellet projects beyond threads, setting up counter-thrust when assembled and creating strong metal-to-metal contact. Nuts will not loosen under severe vibration and withstand temperature ranges from −70 to +250 F. **Nylok Corp.**, 611 Industrial Ave., Paramus, N. J.

Circle 457 on page 19

Thermostatic Controller

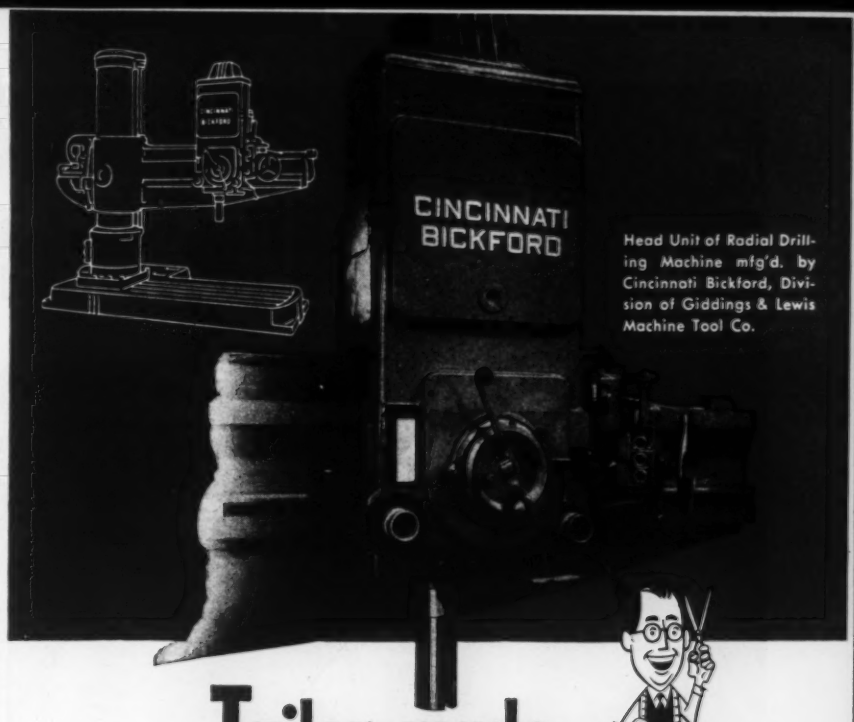
controls 200 F wide range to 600 F maximum



Pilot-type thermostatic controller for high-temperature applications is available in standard temperature ranges of 250 to 450 F, 350 to 550 F, or any 200-deg range from 50 to 600 F. Thermosensitive tube is stainless steel to withstand corrosion, temperature and erosion. Thermal isolator section keeps pilot valve and adjustments cool on high-temperature control applications. Instrument provides accurate temperature regulation of liquids or air when used in conjunction with valves, dampers or other controls. Rod-and-tube thermal element is immersed directly in medium being controlled, in any horizontal or vertical posi-

(*Continued on Page* 162)

Circle 574 on page 19→



Head Unit of Radial Drilling Machine mfg'd. by Cincinnati Bickford, Division of Giddings & Lewis Machine Tool Co.

Tailor-made CASTINGS*

65 in Cincinnati Bickford Head Unit

Producing castings for today's precision machine tools demands the ultimate in technical skill. That's why machine tool manufacturers, such as Cincinnati Bickford, specify castings "tailor-made" by Hamilton Foundry. They know it pays to take advantage of Hamilton Foundry's well-earned reputation for "tailoring" castings to do the jobs they were designed to do!

At Hamilton Foundry, you'll find the most rigid adherence to the design engineer's specifications plus a wide variety of irons that meet physical properties required by service conditions. And you can stop worrying about intricate designs . . . tight dimensional tolerances . . . and wide range of metal sections.

P.S. Above photo shows the Head Unit of Cincinnati Bickford's 7 foot, 19" column, Super Service Radial Drilling Machine, featuring complete hydraulic pre-selection of all 36 speeds and 18 feeds. This Head Unit contains a total of 65 "tailor-made" HAMILTON QUALITY CASTINGS® with a weight range of 0.3 lbs. to 804 lbs.

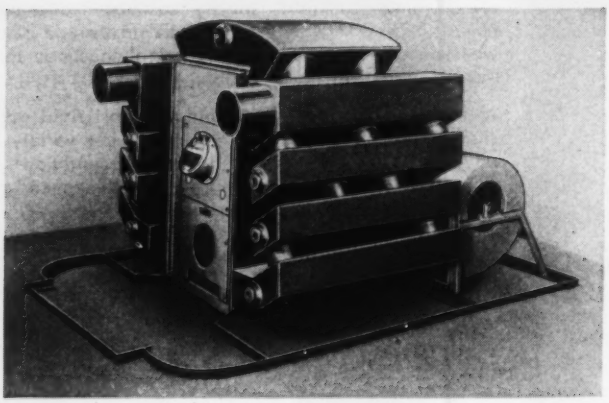
Call on Hamilton Foundry for "tailor-made" castings.

GRAY IRON · ALLOYED IRON
MEEHANITE · NI-RESIST · NI-HARD

THE HAMILTON FOUNDRY
AND MACHINE CO.
1551 Lincoln Avenue · Hamilton, Ohio
Phone TWinbrook 5-7491

H56-4

Alloy steel cap screws



SAFE, GAS-TIGHT JOINTS required by the down-flow construction of this year-round furnace and air-conditioning unit are easy to obtain, using Republic ELECTRUNITE® Mechanical Tubing. Its uniform roundness, wall thickness, strength and ductility help simplify design and fabrication. Quality control from raw ore to finished product assures long, trouble-free service.

REPUBLIC

REPUBLIC STEEL

World's Widest Range of Standard Steels

assure hermetic seal permanence

One of the most critical points in maintaining an absolute hermetic seal in any refrigeration system is the joint between compressor cylinder and head. That's why Copeland Refrigeration Corporation of Sidney, Ohio, manufacturer of fine commercial refrigeration and air conditioning compressors, insists on cylinder head cap screws made to exacting specifications. Republic Alloy Steel Hex Head Cap Screws fill the bill perfectly. They more than meet tensile strength, yield point, hardness and ductility requirements.

Design of the Copeland Compressor calls for cap screws to clamp cylinder head, a neoprene gasket, valve plate, another neoprene gasket and cylinder block into one solid, leakproof assembly. Year-in, year-out service dependability demands that these fasteners neither stretch nor lose their grip under the heating and cooling cycle of on-off operation. There must be no loss in compression or escape of refrigerant. Again, Republic Alloy Cap Screws are more than equal to the task—as proved by their failure-free performance record.

Whatever your fastener problem, it will pay you to check Republic. 20,000 standard and 8,000 special types and sizes of headed and threaded products are available to satisfy a tremendous variety of applications. Each is backed by a century of experience, and quality controlled from raw ore to finished product.

You can get complete information through your local Republic office. Or simply mail the coupon.

OUTSTANDING PRODUCT PERFORMANCE is assured when you specify Republic Hot Rolled Carbon or Alloy Bars as your raw material. A full range of standard and special shapes, sizes and grades is available to meet the most exacting requirements. Further, Republic's 3-Dimension Metallurgical Service can help you select the proper type, and process it efficiently.

ZINC COATING PERMANENCE makes Republic Continuous Galvanized Sheet ideal for hundreds of mass-produced parts and products. Its uniform, corrosion-resistant zinc coating will not crack, flake or peel under any forming operations permitted by the base metal. Resulting product is far less expensive to produce than old-fashioned, hot-dipping after fabrication would allow. Send coupon for information.

STEEL

and Steel Products

REPUBLIC STEEL CORPORATION
Dept. C-2405
3130 East 45th Street
Cleveland 27, Ohio

Please send me further information on:

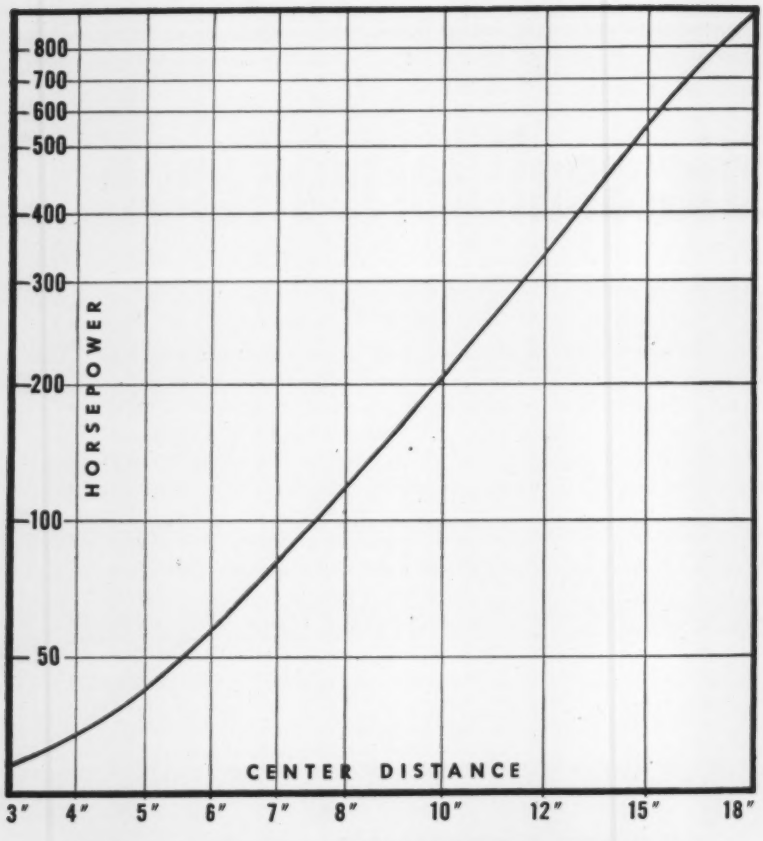
☐ Fastener Products ☐ Continuous Galvanized Sheets
☐ ELECTRUNITE Mechanical Tubing ☐ Hot Rolled Bars

Name_____ Title_____

Company_____

Address_____

City_____ Zone____ State_____



WE LEFT COMPETITIVE RATINGS OUT OF THE CHART PURPOSELY..

... because we think the load-carrying capacity of Cone-Drive speed reducers is pretty impressive all by itself. Then, we've also got a lot of friends in the worm gear speed reducer business. And they make pretty fair reducers themselves.

Two things are responsible for the high capacity of Cone-Drive speed reducers. First, we use extra-heavy gears mounted on oversize taper roller bearings in reinforced, heavy housings. Extra "beef' alone accounts for part of our capacity.

Even more important, however, is the Cone-Drive double-enveloping worm gear design. Here, we literally wrap worm and gear around each other to put ⅛ of all teeth in continuous full-depth contact. This results in spreading tooth contact over a greater area, reducing pressure on individual teeth, increasing load capacity and life of the gearing.

Ask for Bulletin 600C without obligation.

CONE-DRIVE GEARS
DOUBLE ENVELOPING GEAR SETS & SPEED REDUCERS
Durston Michigan Tool Company
7171 E. McNichols Road • Detroit 12, Michigan

Circle 576 on page 19

New Parts

(*Continued from Page* 159)

tion. Controller is 3 13/16 in. wide by 19¾ in. long and is recommended where compressed air is used as pilot supply. **Robertshaw-Fulton Controls Co.,** Fulton Sylphon Div., Box 400, Knoxville, Tennessee.

Circle 458 on page 19

Teflon Hose Assemblies

in sizes from 3/16 to 1⅛ in.

Chemically resistant, flexible hose assemblies consist of a Teflon liner encased in stainless-steel wire braid, with full-flow fittings permanently locked to the hose. Units handle sustained operating pressures to 4000 psi at temperatures from −100 to 500 F. The assem-

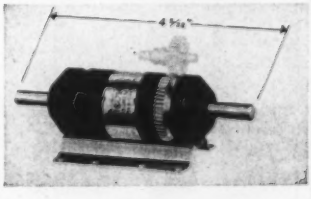
blies are recommended for use where chemical resistance, freedom from contamination, wide temperature and pressure range, and flexibility are required. Eight sizes are available from 3/16 to 1⅛ in. with maximum length of 50 ft. **Mic-Lin Co.,** Route 38 at Rudderow Ave., Maple Shade 6, N. J.

Circle 459 on page 19

Miniature Differentials

are available with or without antibacklash feature

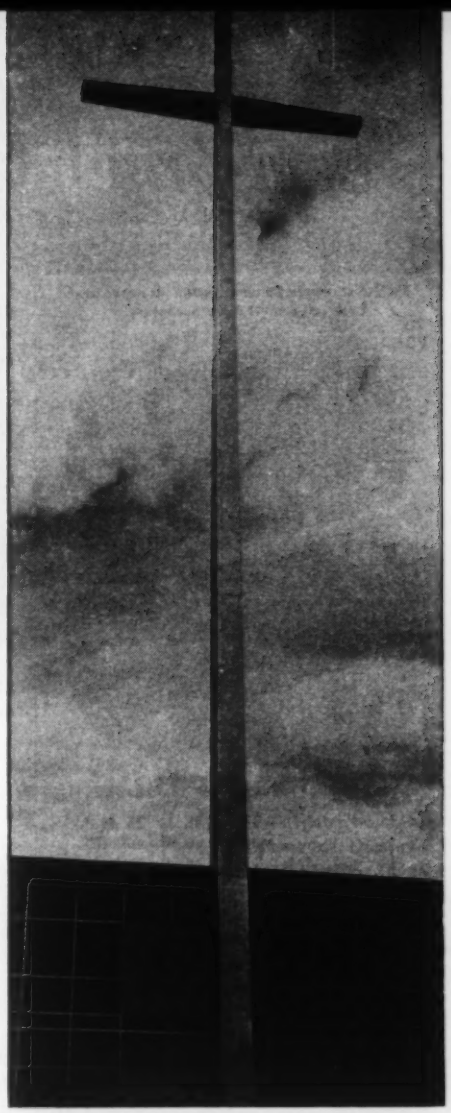
These miniature differentials have application where small size and long life are required. They add or subtract two rotating inputs or



angular inputs and control relative speeds, obtaining wide speed ratios between shafts. Differentials reverse or change speeds quickly without disconnecting the power

FOR CORROSION RESISTANCE. The Marathon Corporation developed a method of producing lignosulfonates from paper mill sulfite liquor, but it was impractical until Stainless Steel became available in the 1930's. The plant now produces 75 million pounds a year, and 50% of the equipment is Stainless Steel.

NOTHING *can equal* *Stainless Steel*



FOR ENDURING BEAUTY. This great religious symbol is erected on the grounds of St. Patrick's Academy, Chicago, Ill. The Stainless Steel skin furnishes a gleaming, permanent inspiration to all viewers.

• No other design material can match Stainless Steel in its *combination* of desirable properties: corrosion resistance, strength and hardness, beauty, cleanability and easy fabrication. When buying Stainless, remember that United States Steel offers the widest range of types, finishes and sizes available in the United States.

FOR WET, ABRASIVE SERVICE. Here's a Stainless Steel shaker screen in a coal plant. Management says, "Ordinary screens would only last about two weeks, but we can expect three *years* of service from these Stainless Steel screens . . . "

UNITED STATES STEEL CORPORATION, PITTSBURGH • AMERICAN STEEL & WIRE DIVISION, CLEVELAND
COLUMBIA-GENEVA STEEL DIVISION, SAN FRANCISCO • NATIONAL TUBE DIVISION, PITTSBURGH
TENNESSEE COAL & IRON DIVISION, FAIRFIELD, ALA.
UNITED STATES STEEL SUPPLY DIVISION, WAREHOUSE DISTRIBUTORS
UNITED STATES STEEL EXPORT COMPANY, NEW YORK

USS STAINLESS STEEL

SHEETS • STRIP • PLATES • BARS • BILLETS
PIPE • TUBES • WIRE • SPECIAL SECTIONS

USS

UNITED STATES STEEL

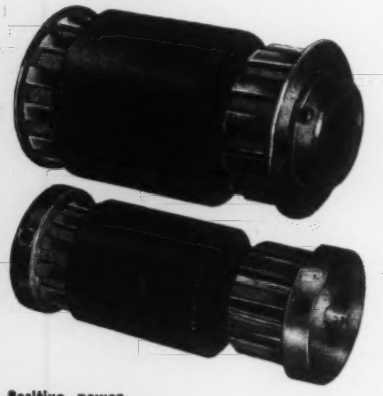
Circle 577 on page 19

NEW . . . NEW!

Gear-Grip

Flexible Coupling

The most revolutionary design advancement for integral H.P. in a century!

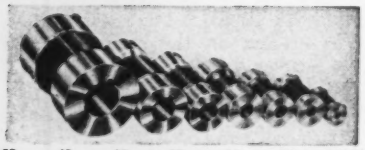


Positive power transmission of rated load. Gear teeth on end casting match special rubber tube section.

- **Load ranges—2½ H.P. to 25 H.P.**
- **Shaft sizes—¾" to 1⅞".**
- **Specified lengths to design requirements.**
- **Prevents end thrust.**
- **"By Eye" shaft alignment.**
- **No lubrication required.**
- **Shaft Safety features.**

Dyna-Line . . .

The finest flexible coupling in single unit construction—specifically designed for fractional H.P.



5R 4R 3R 2R 1R 0R 00R

- **True Flexibility and Torsional Resilience for quiet, load-plus power transmission without extreme deflection or twist.**
- **Lengths varied to design specifications in each series.**
- **Load ranges—1/15 to 1½ H.P.**
- **Shaft sizes — 3/16" to ¾".**
- **Lowest O.D. for highest torque capacity.**

Write for Catalogs and Technical Bulletins.

Guardian
PRODUCTS CORP.
COUPLING DIVISION

DEPT. M-116, 1215 E. SECOND ST.
MICHIGAN CITY, INDIANA

Circle 578 on page 19

New Parts

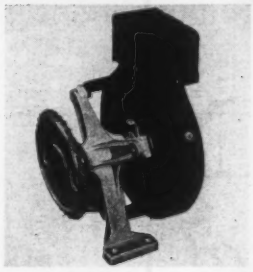
source. Units have sealed construction, hardened gears and foot-mounted ball-bearing shaft supports. Thirty-four ratios from 1:1 to 27:1 are provided. All gears are hobbed for smooth operation. The differentials are available with or without antibacklash feature. **Metron Instrument Co.**, 432 Lincoln St., Denver 3, Colo.

Circle 460 on page 19

Rheostat

provides speed control for multi-motor drives

Rheostat is for use on multi-motor drives where relative speeds between motors must be maintained within specified limits. Rheostat affords reliable field control method essential to service in textile,

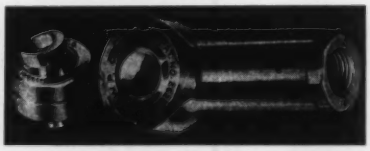


paper, steel mills and other process machinery. Assembly comprises a single or multi-deck 6, 8 or 13 in. steel rheostat with thru shaft and mounting bracket. Control of single or multiple circuits from a single assembly is possible. Unit provides up to 161 control steps per plate and requires ½ to 1½ in-lb per plate operating torque. **Ward Leonard Electric Co.**, Mount Vernon, N. Y.

Circle 461 on page 19

Self-Aligning Bearing

for bolts or nonrotating shafts



Self-aligning bearing consists of two pieces: A spherical ball with hole for bolt or shaft, and a one-

MODERN ELECTRONIC ENGINEERING GIVES PRECISE MOTOR SPEED CONTROL

Modern industrial electronic engineering has been coordinated with electric motor design to provide a versatile means for obtaining the full possible advantage of speed control in DC motors while operated from the regular alternating current power line. Grid controlled "Thyratron" tubes are utilized for power controlled stepless variation to supply motor armature power. Patented feedback, or "Servo" circuits provide constant torque capability over wide speed ranges of as high as 60 to 1 in some models and a minimum of 20 to 1 in others.

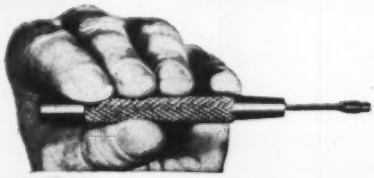
Servospeed
DIV. of ELECTRO DEVICES, Inc.
4 Godwin Ave., Paterson, N. J.
ARmory 4-8989

Circle 579 on page 19

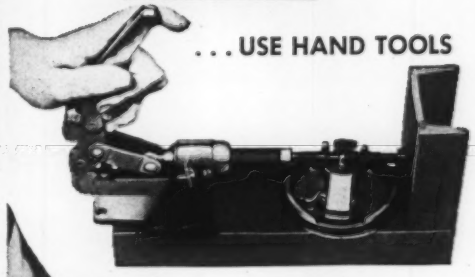
How Rollpin cuts assembly costs

by matching the insertion method to the assembly problem

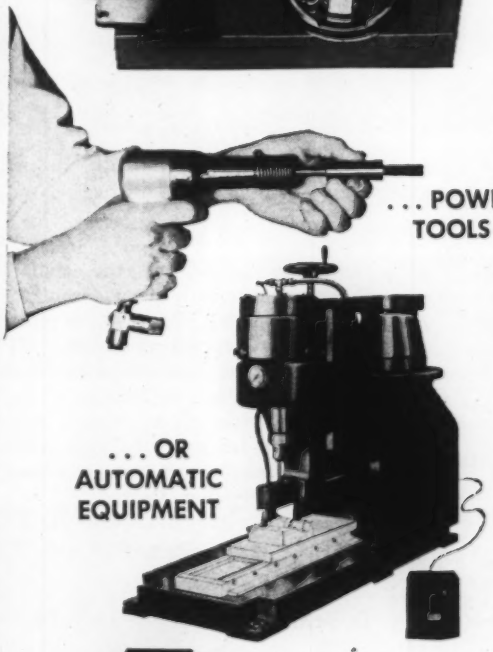
HAMMER IT IN . . .



. . . USE HAND TOOLS



. . . POWER TOOLS

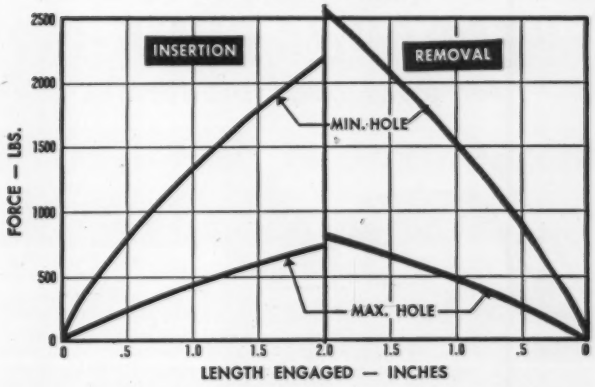


. . . OR AUTOMATIC EQUIPMENT

It's as easy to insert a Rollpin® as it looks. And it's fast any way you do it. You can use a hammer, hand tool, power tool or automatic equipment. Insertion cost is less because no precision drilling or reaming or secondary locking operations are required. A hole drilled to normal production standards will do.

Rollpin is a slotted, chamfered, cylindrical spring pin. It locks securely in place—and can be drifted out and reused over and over again. Rollpin replaces taper pins, straight pins and set screws; for many applications it will serve as a rivet, dowel, hinge pin, cotter pin or stop pin.

TYPICAL INSERTION AND REMOVAL FORCES IN STEEL FOR .250" DIAMETER ROLLPIN



WHY ROLLPIN IS SELF-LOCKING. Here is graphic evidence of the forces that make Rollpin a truly self-locking spring type fastener that will remain tight under vibration until deliberately removed.

ELASTIC STOP NUT CORPORATION OF AMERICA

Dept. R45-114, 2330 Vauxhall Road, Union, New Jersey

Please send me the following:

☐ Rollpin installation data ☐ Here is a drawing of our fastening problem. What insertion method would you suggest?

Name _____ Title _____

Firm _____

Street _____

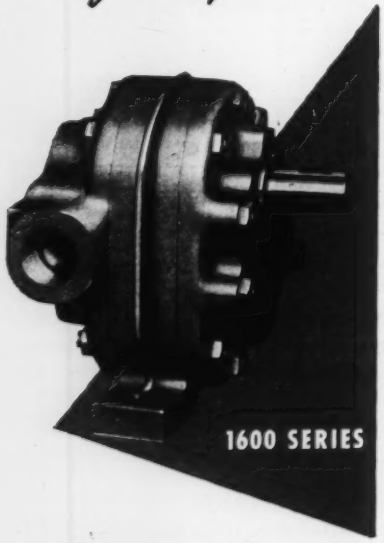
City _____ Zone _____ State _____

Circle 580 on page 19

The new **ROPER**

HYDRAULIC PUMP-MOTOR

for Improved **INDUSTRIAL SERVICE**



Designed by the same engineers who developed the famous Roper Rotary Pumps, the new Roper Hydraulic Pump-Motors operate on the same principle using two equal size, smooth-running gears in a precision-fitted case. These units offer low-speed and high-torque (much needed in the hydraulic field), and their versatility finds them well-suited to heavy-duty service within their operating range. They run equally well in either direction both as pumps or motors . . . they can be direct-connected without speed reducers, thus conserving space . . . they are easily installed, easy to operate, and are long on economy. Perhaps *you* have equipment that can be further improved with a Roper Hydraulic Pump-Motor. Send for all the facts today.

PERFORMANCE CHARACTERTISTICS

Available in foot and flange mounted models. Recommended speed range on larger sizes is from 200 to 800 RPM with pressures to 800 PSI In this range, Roper units require from 7 to 40 GPM flow and will develop up to 11.5 HP output at maximum speed and pressure. Smaller sizes may be operated up to 1200 RPM and up to 800 PSI which will require a flow of 16 GPM to develop up to 5 HP.

SEND FOR BULLETIN 22

ROPER Rotary Pumps

GEO. D. ROPER CORPORATION • 251 Blackhawk Park Ave., Rockford, Ill.

New Parts

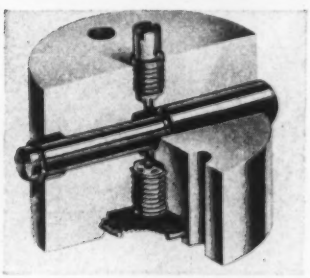
piece outer race. Unit is for applications where self-alignment is required for a bolt or nonrotating shaft in aircraft or similar structures subject to deflection, twisting or vibration. Available in both plain and rod-end types, unit has bore range of 3/16-in. to 3 in. and ultimate load range from 3000 to 893,000 lb. Ball is hard chrome plated. Race materials are high-strength bronze, steel or stainless steel. **Southwest Products Co.**, 1705 S. Mountain Ave., Duarte, Calif.

Circle 462 on page 19

Oil Pump

piston-type unit has one moving part

Continuous lubrication is provided by a rotating pump with an oscillating piston. Unit consists of a 3 in. diam cylindrical housing containing a horizontal stepped piston. It is designed primarily for lubrication of machines with vertical drive shafts and is attached directly to bottom of the shaft. Pump rotates in a fixed eccentric race in sump. Ends of piston, extending beyond diameter of housing, ride against eccentric race. Resulting oscillating action of piston draws oil into pump and feeds it under pressure into bore of drive shaft and to bearings. **Bijur Lubricating Corp.**, 151 W. Passaic St., Rochelle Park, N. J.

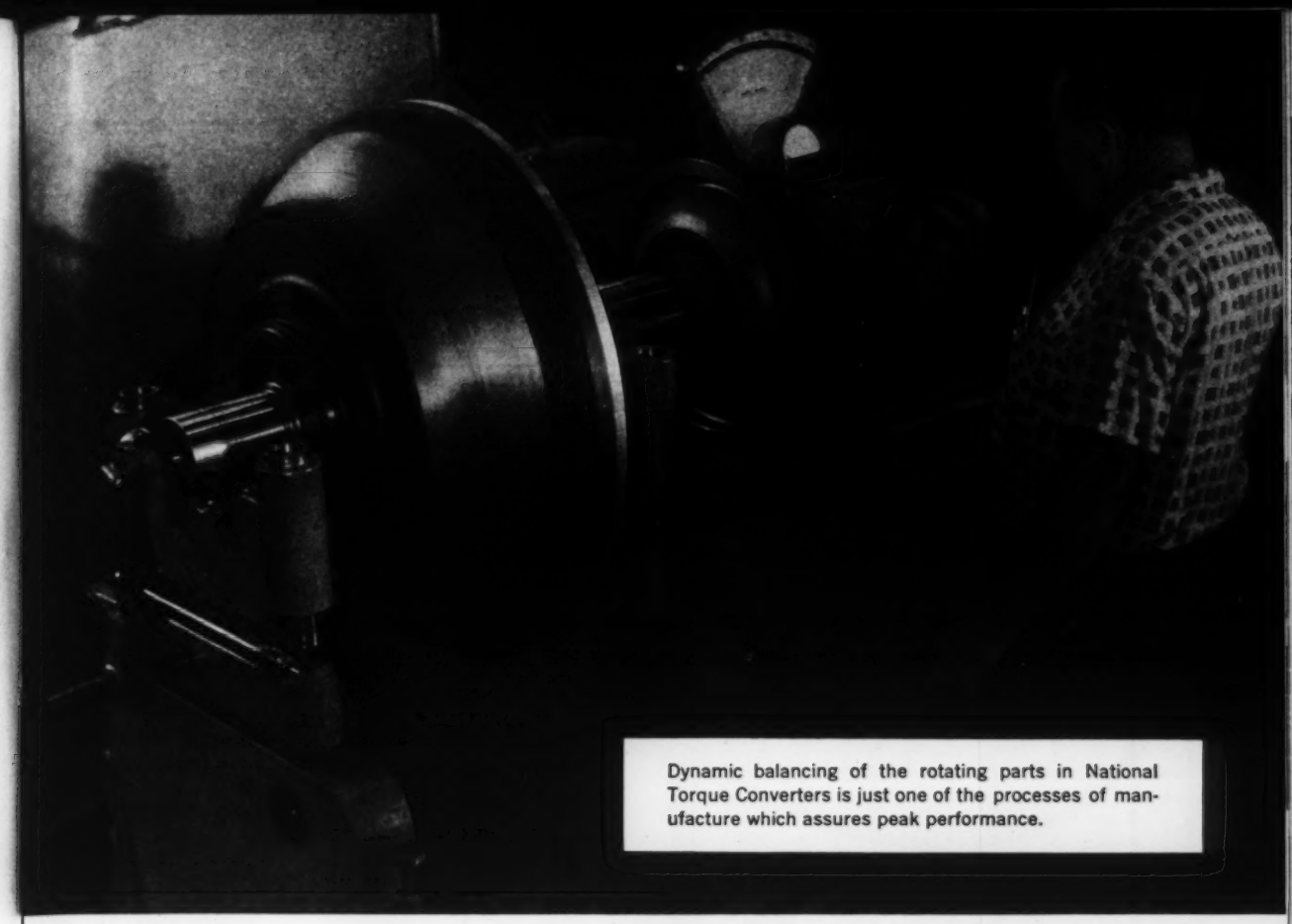


Circle 463 on page 19

Switching Control

provides low-power automatic switching

Static switching control system accomplishes control functions usually performed by contact making devices such as relays. Sys-



Dynamic balancing of the rotating parts in National Torque Converters is just one of the processes of manufacture which assures peak performance.

Dependable heavy-duty performance is engineered and built into National Torque Converters

Heavy machinery demands exceptional torque converter performance. Examples of this are earth-handling and excavating equipment, mining, and oil field drilling equipment.

To meet the most exacting service demands, in a wide variety of industrial applications, a full line of heavy duty National Torque Converters are available. These are designed and built with a broad range of performance characteristics and in horsepower ratings to match torque converter to prime movers of 100 to 1000 hp in virtually any application. The torque converters are engineered for the specific equipment application.

Precision fabrication of parts . . . exhaustive tests of component parts, of sub-assemblies, and of complete torque converters . . . assure long, trouble-free service of each National Torque Converter, with a minimum of attention from the operator and with minimum expense to the owner.

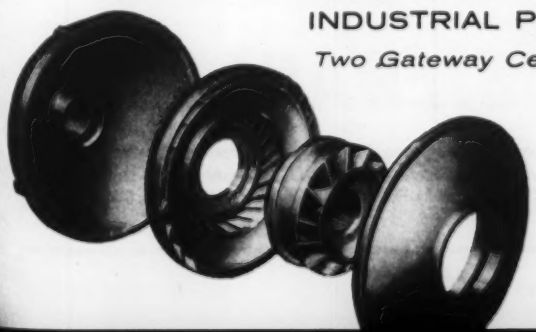
That means that when you select a National Torque Converter to match a specific engine or motor in a specific application, you can be sure of duplicate results from each succeeding National Torque Converter engineered and built to the same specifications.

National Supply engineers will gladly discuss National Torque Converters in relation to your equipment and make recommendations of exact size and torque capacity. Why not call on them?

THE NATIONAL SUPPLY COMPANY

INDUSTRIAL PRODUCTS DIVISION

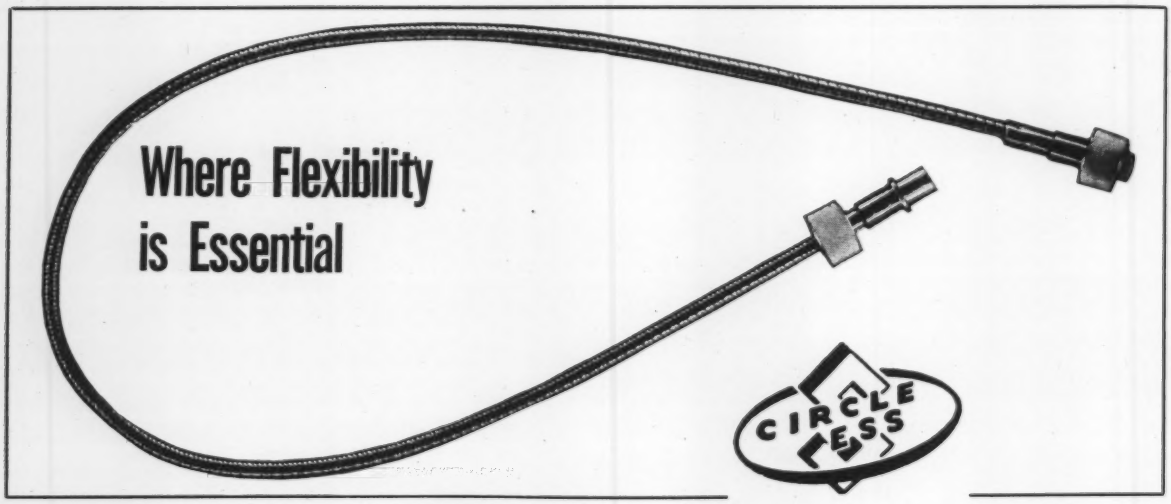
Two Gateway Center, Pittsburgh 22, Pa.



Pace-setters in the progress of industrial power transmission

Circle 582 on page 19

ECONOMY + PERFORMANCE

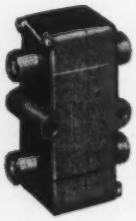


RIGHT ANGLE ADAPTER

To provide a connection for flexible shaft control where space limitations do not permit a conjunction without bending the shaft into too small a radius.

H TYPE ADAPTER

This adapter provides three outlets, which enables the running of three units from the same power source. Ball bearing construction enables this adapter to handle heavy loads.

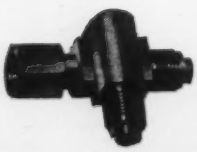


BALL BEARING RIGHT ANGLE ADAPTER

To provide a connection for flexible shaft control where a bend sharp enough to damage the shaft is required. Ball bearing construction enables the handling of heavier loads.

DUAL DRIVE ADAPTER

To drive more than one unit from the same power source and to provide two gear ratios from the same power source.



Flexible Shafting Offers You

Direct alignment in either remote control or power transmission.

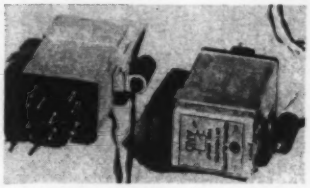
Less working units needed in flexible shafting direct grouping.

Sturdier construction but lighter weight.

Write on your letterhead for our latest Flexible Shaft Manual

F. W. STEWART CORP.

4311-13 RAVENSWOOD AVENUE · CHICAGO 13, ILLINOIS
WEST COAST PLANT: 1638 So. FLOWER STREET · LOS ANGELES 15, CALIFORNIA



tem is designed to aid in automation of low-power switching operations. Consisting of complete line of static components, unit provides the five logic functions basic to intelligence switching: And, Or, Not, Memory, and Time Delay. Switching control can be furnished in component form or in complete panels and systems. Design permits unit to be combined with other regulating systems of static type, allowing co-ordinated overall static control. Fail-safe circuitry is provided and circuit will resume operation after power failure at same point in cycle where it left off. Static systems are useful where frequent or continuous operations are needed or where complex systems or adverse environmental conditions exist. **General Electric Co.**, 1 River Rd., Schenectady 5, N. Y.

Circle 464 on page 19

Zinc Bright-Dip

powder produces mirror finish

One-dip process produces mirror-like, iridescent-free surface on zinc plating with no brighteners in zinc bath. Powder, known as Kenvert No. 16, operates satisfactorily in temperature range of 90 to 110 F with no ventilation required. Bright-dip offers excellent corrosion protection and unusual resistance to staining and fingerprints. **Conversion Chemical Corp.**, Rockville, Conn.

Circle 465 on page 19

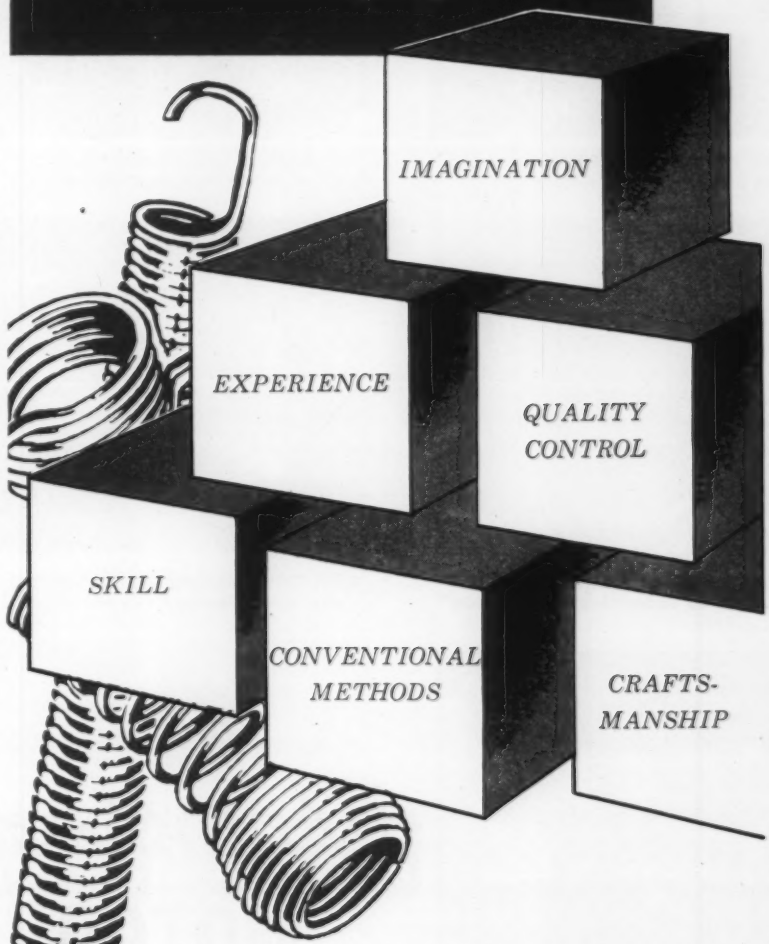
Snap-On Duct

speeds installation and servicing of wires

Snap-on duct simplifies installation of control panel wiring. Unit is external, requiring no usable wiring space, and eliminates pos-

(Continued on Page 172)

BUILDING BLOCKS
for Accurate Springs



Conventional, accepted standards of manufacturing springs are a building block at Accurate Springs. So are skill, craftsmanship, experience, quality control—*and imagination!* It all adds up to a better spring, at lower cost, held to closer tolerances—*for YOU.*

Accurate Springs

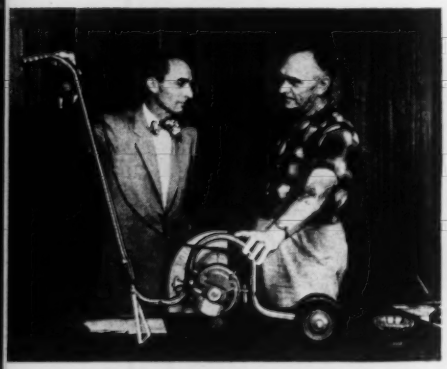
ACCURATE SPRING MFG. CO.
3824 West Lake Street
Chicago 24, Illinois

SPRINGS • WIREFORMS • STAMPINGS

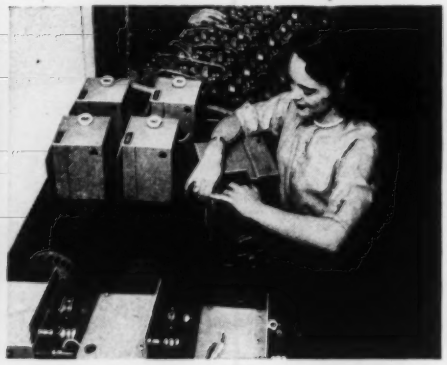
RED JACKET MANUFACTURING CO.
"jet pumps cost less to ship"

LENNOX INDUSTRIES INC.
"we just install them and forget them"

W. M. WELCH MFG. COMPANY
"eliminated heavy mounting frames"



K & S MANUFACTURING COMPANY
"stands up under roughest handling"

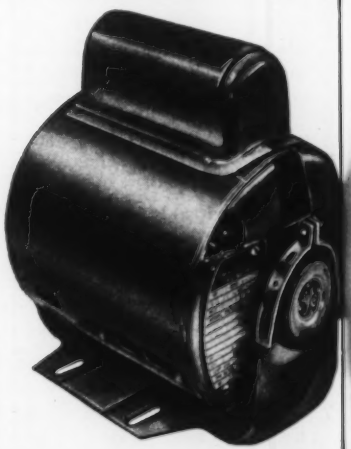


ANTHONY MACHINE & ENG. SERVICE
"*only* motor versatile enough for us"

THE TRANE COMPANY
"reduced product weight nearly 8 lbs."

RUTHMAN MACHINERY COMPANY
"more compact, yet full-powered"

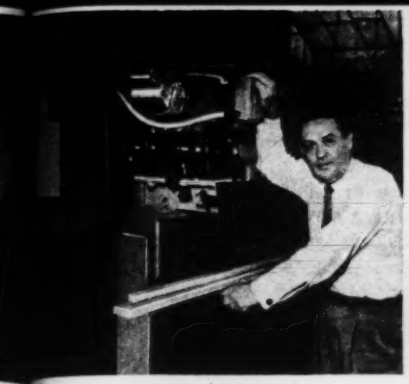
Years Ahead
MOTOR



ALBERTSON & CO.—SIOUX TOOLS
"lighter, smaller—with power to spare"

MODINE MANUFACTURING COMPANY
"dependable—in operation *and* delivery"

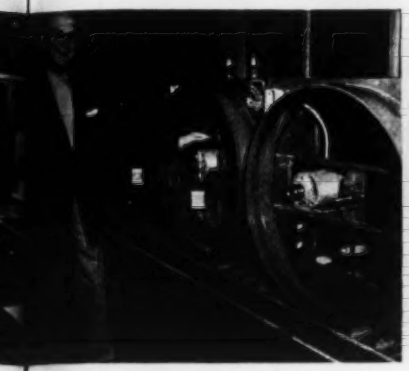
BARBER-COLMAN COMPANY
"cut manufacturing costs 12%"



AUTO-NAILER COMPANY
"All-angle mounting cuts design costs"

G. C. BREIDERT COMPANY
"as quiet as it is dependable"

LANCASTER PUMP & MFG. CO.
"G-E motors help sell our pumps"



BAR-BROOK MFG. COMPANY
" 'no re-oiling' feature rates high"

SOUTH BEND LATHE COMPANY
"top quality at competitive prices"

TEMCO, INC.
"light weight cut shipping costs"

16 More Companies Say...

LESS COSTS, MORE SALES with General Electric fhp motors

Yes—16 *more* manufacturers, like yourself, have reported on the cost-savings and sales-increases they've realized by incorporating General Electric "Years-ahead" motors into their products.

They are representative of the thousands of companies who have realized similar benefits—adequate proof that this General Electric fhp motor *can* save you money—*can* make your product more saleable.

And no wonder! The G-E "Years-ahead" motor incorporates a number of advanced design features to give you longer motor life, unsurpassed versatility, and a lighter, smaller, more streamlined design to match your own modern product . . . for example—moisture resistant Mylar* polyester film insulation; dependable, all-angle sleeve bearings; doubled lubrication life; removable, rotatable cradle base; and many others.

To find out how you can take greater advantage of these G-E motor benefits in your own product, contact your nearby General Electric Apparatus Sales Office, or write to General Electric Company, Section 702-30, Schenectady, N. Y.

*Registered trade-mark of Du Pont Company.

GENERAL ELECTRIC

Circle 584 on page 19

Photo courtesy Nutone, Inc., Cincinnati

Engineers Develop New Use for Rubber

Rubber, normally used to *reduce* vibration, now can be made to *increase* vibration

Here rubber grommets serve as mountings for the tone bars in Nutone Door Chimes. To obtain maximum tone quality and resonance required of these musical chimes, the grommets must vibrate compatibly with the tone bars . . . a truly *unusual assignment* for rubber.

Only by skillful compounding can rubber be diverted from its normal dampening characteristic and be given this vibrant quality. The slightest deadening effect would destroy the rich tones and kill the tone hang.

The successful development of this lively, age-resistant rubber stock typifies the complete engineering and laboratory—as well as manufacturing—skill available at Continental. Whenever you need "engineered rubber parts" — molded or extruded, natural or synthetic—call Continental, Specialists since 1903. **Engineering catalog.**

In addition to custom-made parts, Continental offers an extensive line of standard grommets, bushings, bumpers, rings and extruded shapes. Hundreds of these are shown in the No. 100 Engineering Catalog. Send for a copy or refer to it in Sweet's Catalog for Product Designers.

Another achievement in **RUBBER**

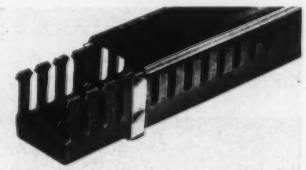
engineered by **CONTINENTAL**

CONTINENTAL RUBBER WORKS • 1984 LIBERTY ST. • ERIE 6 • PENNSYLVANIA

New Parts

(*Continued from Page* 169)

sibility of shorts to fastener and mounting screw. Cadmium plated, U-shaped spring clip fastens to control panel with screws. Duct snaps into clip, wiring fits into duct slots, and cover snaps onto



duct. Cover may be removed by pressing in on clip. Duct provides easy method of inserting and removing wires since they may be snapped in and out of duct with lugs attached, eliminating need for threading wires through side of duct. **Panduit Co.**, 10132 S. Washtenaw, Chicago, Ill.

Circle 466 on page 19

Threaded Cast Iron

has tensile strength to 45,000 psi

This threaded stock is of alloyed and processed close-grained cast iron, free from blow holes, and is heat-treated and stress relieved for tensile strength to 45,000 psi. High

graphitic content material has high wear resistance and long service life. Processed from 12 in. bar and threaded for 11 in., the stock is available in 8 diameters. Special sizes and pitch diameters are also available in alloy and low carbon steel, nonferrous and stainless steel. **Claude Sintz Inc.**, 1928 Stanley Ave., Detroit 8, Mich.

Circle 467 on page 19

Time Switch

controls on-off cycles during 24-hour period

TSA 555 time switch with multiple tripper dial has flexibility of time setting to permit use where varied on-off schedules are required dur-

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are the easiest

in stock

to get

in stock

mean faster deliveries from stock!

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LINE-O-POWER SPEED REDUCERS

Standardized interchangeable gearing – by Foote Bros. – lets you specify and get the particular reducer you want, in the quantities you need, direct from stock! Duti-Rated Lifetime Gearing in a complete range of interchangeable sizes, ratios and capacities are stocked and ready for assembly. Capacities range up to 200 H. P., ratios to over 2700 to 1. Standard foot and flange type cast housings are stocked, too, for straight or right angle drives. The drives you want are assembled from stock components and shipped as soon as your order is received. For a complete index to the almost endless variety of Line-O-Power reducers immediately available, write for your copy of the Line-O-Power catalog today. See for yourself how you can get more for your drive dollar . . . faster!

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Better Power Transmission Through Better Gears

FOOTE BROS. GEAR AND MACHINE CORPORATION

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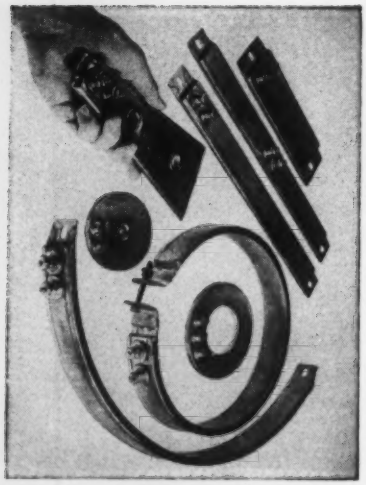
Circle 586 on page 19

XUM



New manufacturing process improves performance of CHROMALOX Electric Strip Heaters

An improved manufacturing process, combined with a newly developed refractory material, offers you the finest performance in strip heaters. Rugged and long lasting, they are industry's workhorse among heating elements.

So when you use the improved line of Chromalox Electric Strip Heaters, you're assured of even better performance in the heating of platens, dies, kettles, tanks, ovens, air ducts and other applications that require dependable, accurately controlled heat . . . where and when heat is needed.

Let the Chromalox Sales-Engineering staff solve your heating problems—electrically.

Write for your copy of Catalog 50

This data-packed catalog covers the design, uses and prices of the complete line of Chromalox Electric heaters, elements, thermostats, contactors and switches.

To get short factual material on many additional applications of electric heat, send for Booklet F1550 "101 Ways to Apply Electric Heat."

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☐ a copy of "101 Ways"
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Company_____

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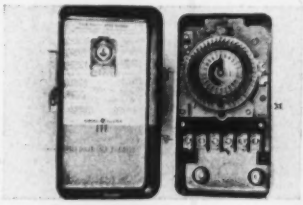
A-4484A

Circle 587 on page 19

New Parts

ing a 24-hr period. Such applications include heating, air conditioning, refrigeration and operation of automatic machines. Trippers are permanently fixed in the timer dial, but can be removed and relocated with a screwdriver. Slots are located at each ¼-hr point on the



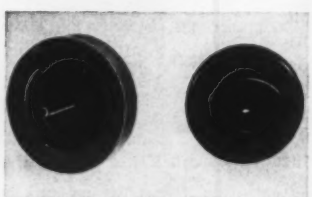
dial. Minimum on time is 15 minutes; minimum on-off cycle, 45 minutes. Voltage for the timing device is 120, 240 or 480, and frequency is 60, 50 or 25 cycles. Power source is a 4-w motor that operates at temperatures from −50 to 150 F. Optional features include a weatherproof case for outdoor applications, an omitting device and a pair of intermittent contacts which provide undervoltage protection and automatic sequence restarting if power fails. **General Electric Co.**, Instrument Dept., One River Road, Schenectady 5, N. Y.

Circle 468 on page 19

Lead-Plastic Compound

is harder and more rigid than lead

Lead-plastic compound is both harder and structurally more rigid than pure lead. Known as Leadcast, material may be molded with any metallic inserts with excellent bonding. Molded shape tolerance is ±0.005-in. and surface is



smooth, requiring no finishing. Material is inert to oxidation or other corrosive contamination. Amount of lead can be up to 95 per cent by weight; hardness can be controlled from that of a semirubber like material to the hardness of cast aluminum. Applications are

YOU WOULDN'T BUY

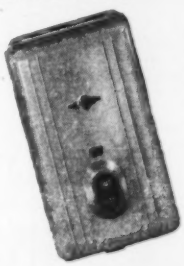
A HAT THAT'S TOO BIG!

SO WHY BUY A CONTROL THAT'S THE WRONG SIZE?

FURNAS

MAGNETIC CONTROLS GIVE YOU CORRECT CAPACITY FOR THE JOB!

The many in-between sizes in the Furnas Electric starter line let you select the motor control that is best suited for your particular requirements—with no wasted capacity and expense. Match the starter to the job and save up to 25%. For proof, compare the 9 sizes of the Furnas Electric starter line with the 5 sizes normally offered. And you can save up to 40% in space by using the correct size starter.



For more information write for Bulletin 5530—1045 McKee Street, Batavia, Ill.

A11

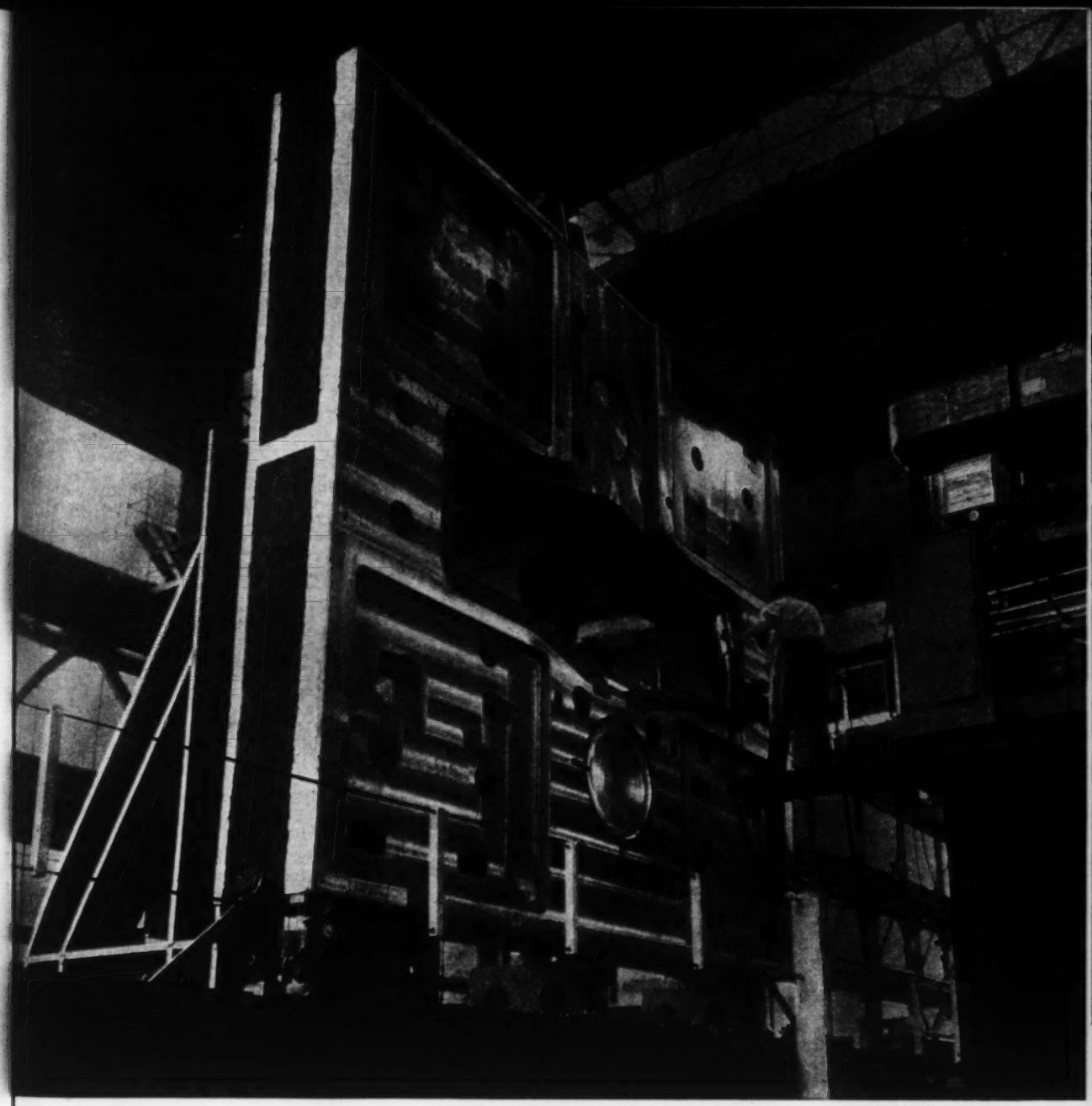
FURNAS

FURNAS ELECTRIC COMPANY

BATAVIA, ILLINOIS

Sales Representatives in all principal cities

Circle 588 on page 19



95-ton casting for counterblow forging hammer

This steel casting is of interest for several reasons, not the least of which is its size. By any standards it is a big one—approximately 223 in. long, 202 in. wide, 28 in. deep. As you see it here it has been planed on both sides, and the pockets on the side facing the camera have been milled out.

The huge casting will be used as the base plate of a counterblow forging hammer. The intricate piece was cast in one of the Bethlehem foundries, then moved to a neighboring Bethlehem shop for machining. The plans called for a finished weight of 189,000 lb—almost 95 tons.

Heavy castings like this have been a Bethlehem specialty for years. In design they have ranged from the very simple to the highly complex and difficult. You will almost always see many unusual types of castings in Bethlehem's foundries and machine shops, which are equipped to handle an unlimited variety of work.

If your own jobs require steel, iron, or bronze castings, large or small, we suggest that you be sure to investigate the services Bethlehem offers. They leave nothing to chance. When you are next in the market, we will welcome your inquiries.

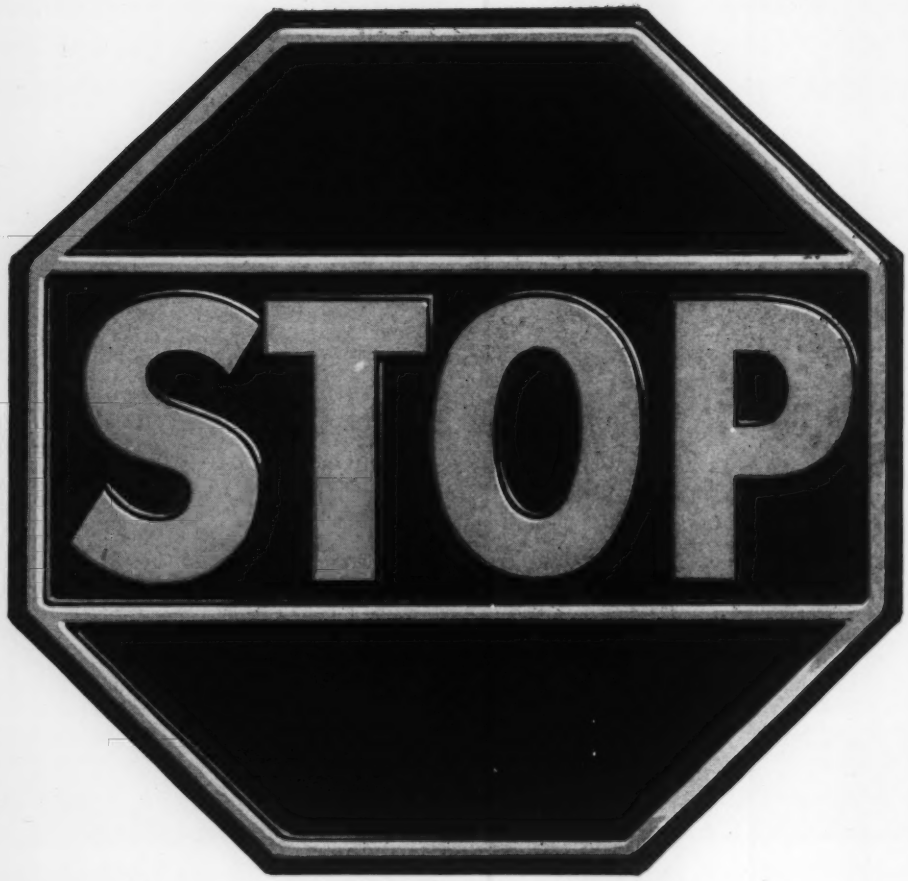
BETHLEHEM STEEL COMPANY, BETHLEHEM, PA.

On the Pacific Coast Bethlehem products are sold by Bethlehem Pacific Coast Steel Corporation. Export Distributor: Bethlehem Steel Export Corporation

BETHLEHEM STEEL

BETHLEHEM STEEL

Circle 589 on page 19



The drafting stage—not later—is the time to design-in oil seals!

Oil seals are precision products. They are designed to operate under a specific set of conditions. Change just one of those conditions—lubricant, shaft speed, temperature, even bearing position—and a different seal will almost always be needed.

Why chance costly retooling or remanufacture? Specify the correct seal on the drawing-board. And when you do, get all the information there is on new seals, new lip compounds, and mechanical designs. Get it from your National Oil Seal Engineer. His counsel is complete, up-to-the-minute, and accurate. You couldn't buy better oil seal information, yet his help is yours for the asking.

Why "do it yourself?" Call the nearest National Oil Seal Engineer now.

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DIVISION, Federal-Mogul-Bower Bearings, Inc.
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MILWAUKEE, WIS. . . *647 West Virginia Street, BRoadway 1-3234*
NEWARK, N. J. . . . . *1180 Raymond Blvd., MItchell 2-7586*

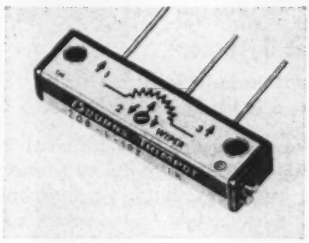
containers for high-energy radiation sources with metal components molded in, housing shielding on instruments, and shipping containers for isotopes or fissionable materials. Material may be formed into construction sizes from wall tile to 4 x 8 ft panels. **Electro Industries Corp.**, 35-18 37th St., Long Island City 1, N. Y.

Circle 469 on page 19

Potentiometer

subminiature unit for printed circuits

Subminiature potentiometer, Model 205, has round-pin terminals for insertion into punched holes in printed circuit boards. Terminals are gold-plated copper, ½-in. long, 0.028-in. in diameter and spaced in 0.1-in. multiples. Units are mounted with 2-56 screws through body eyelets or by pins only. Potentiometer dissipates 0.25-w at 50 C; maximum operating temperature is 105 C. Capacity is from 10 ohm with 2.0 per cent normal resolution to 20,000 ohm with normal resolution of 0.2 per cent. Design also includes 25-turn screwdriver adjustment and self-locking shaft. Unit has excellent shock, vibration and acceleration characteristics, and meets or excels most government specifications. **Bourns Laboratories Inc.**, 6135 Magnolia Ave., Riverside, Calif.



Circle 470 on page 19

Rotary Pump

handles highly corrosive liquids

Low-capacity positive displacement pump of corrosion-resistant metal is designed for movement of fluids such as hydrofluoric acid, hypochlorites, and hydrochloric acid. Pump is of corrosion resist-

"The *ESCO* Engineer said,

'Shellcast this Part'

..we did and we reduced our costs 80%!"

"When the *ESCO* Engineer said, Shellcast *this* part, we at Kenworth Motor Truck Co., Division of Pacific Car and Foundry Co., here in Seattle nearly 'jumped out of our chairs'. Here was a transmission component with many different machined and ground surfaces, so critical, in fact, that we had previously been hard plating them for extra wear after they were machined...our transmission gear-selector bell-cranks *had* to be that good.

"Shellcast more than surprised us for surfaces were so smooth, tolerances so close and differential hardening processes so exacting that we have since eliminated *all* grinding, *all* plating and *over* 60% of all former machining operations. You can well imagine why we are now Shellcast enthusiasts."

Yes, an *ESCO* Engineer can help *you* save valuable machining and finishing time on many parts. Call him today, let him look over your drawings, he is experienced in helping others cut production costs with *ESCO* Shellcast.

Write for FREE booklet—"CUT PRODUCTION COSTS WITH ESCO SHELLCAST"

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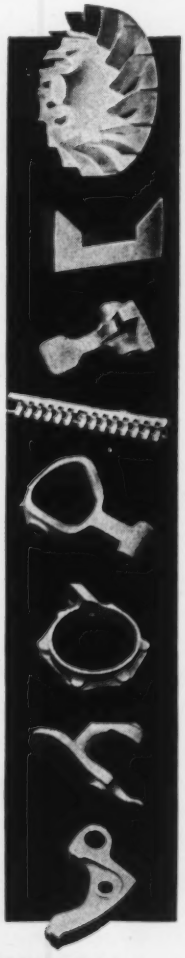
In Canada, ESCO Limited Manufacturing Plants
Vancouver, British Columbia and Toronto, Ontario

Circle 591 on page 19

Westinghouse pilot plant for precision castings speeds development, saves capital investment

Incubator for casting ideas



To help you prove your precision casting ideas and developments under production conditions, Westinghouse invites you to use its new pilot plant facilities at Blairsville, Pa. Thus you can speed your metals programs without heavy capital investment.

Westinghouse will also assist you in creating prototype quantities . . . or give you fast, dependable delivery on production quantities of precision investment castings (lost wax process), shell-mold castings and powder metal parts.

Consider molded metal parts for your product components requiring intricate shapes, close tolerances, difficult machining operations or component assemblies. Westinghouse has skilled metals engineers with broad experience to help show you the way to improved products, lower costs.

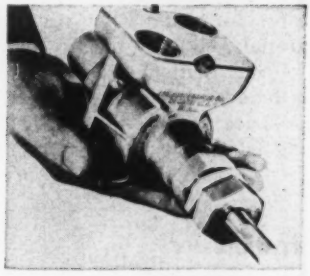
Send today for further details and a copy of DB 52-500. Also enclose a photo, drawing or sample of the part you want evaluated. No obligation. Westinghouse Electric Corporation, 3 Gateway Center, P. O. Box 868, Pittsburgh 30, Pennsylvania. J-05002

WATCH WESTINGHOUSE!

*WHERE **BIG** THINGS ARE HAPPENING **TODAY!***

New Parts

ant Hastelloy C, equipped with internal Teflon bearings and packing, and impeller materials of Tef-



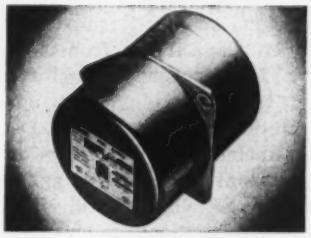
lon, Neoprene, Hypalon or Formica. Rated capacity is 10 gpm. Pump will handle fluids with viscosity to 900 SSU at temperatures to 250 F and is available with a wide range of mountings and drives. **Eco Engineering Co.**, 12 New York Ave., Newark 1, N. J.

Circle 471 on page 19

Free Gyroscope

withstands 50 *g* shock loads

Free gyroscope has unusual ruggedness and insensibility to mounting and dynamic loads. Instrument has a cast-steel frame mounted inside a structural outer shell having integral CG mounting flange. Shock specification is 50 *g* in all



axes; drift rate is less than 18 min of arc per minute; and potentiometer pickoffs which supply outputs up to 70 v for telemetering and control operations have linearity of ± 0.5 per cent and resolution of 0.09-deg. Remote electrical caging mechanism automatically returns gimbals to fixed reference position. Available as single unit or as pair in free gyroscope set for indication in the three major axes, motor is powered by 115, 200 or 26-v three-phase 400-cycle current. **G. M. Giannini & Co. Inc.**, 918 E. Green St., Pasadena 1, Calif.

Circle 472 on page 19

20 ROLLS OF "SARAN WRAP" EVERY MINUTE

The Dow Chemical Company's production of "Saran Wrap" has leaped from 130,000 rolls to 4,000,000 rolls a month since 1951. This up-swing is due to a new plant, a new flow system, and additional equipment including new machinery equipped with Reliance V★S Drives.

One of the most dramatic applications of V★S Drives is on the final wrapping machines shown here. The drives must be able to start, accelerate to 3500 rpm., and stop more than 20 times a minute.

The most important feature, though, is not the frequent starts and stops, but the delicately controlled acceleration of the drives. "Saran Wrap" is only 1/6th as thick as a human hair, and sharp or jerky starts will cause a break in the sheet and halt production. Reliance Drives do the job day in and day out without a single break due to uncontrolled acceleration.

This feature of V★S Drives, called *Dynamic Response*, is only one of the many facets of Reliance Drives. V★S Drives can regulate tension, synchronize operations, control speed rates, and automatically program speed changes.

Whether you handle a thin film of plastic or steel billets, on a complete production line or a single machine, Reliance can give you better quality, more production, and lower costs through Variable Speed Drives. D-1508

RELIANCE V★S DRIVE ®

Write for bulletin D-2311.

RELIANCE ELECTRIC AND ENGINEERING CO.

DEPT. 2811A, CLEVELAND 10, OHIO · OFFICES IN PRINCIPAL CITIES

Canadian Division: Welland, Ontario

UNDERWRITERS LABORATORIES test and approve

new DINGS Explosion-Proof Magnetic Disc Brakes for Hazardous Locations

The new Dings "700" Series Explosion-proof Magnetic Disc Brakes are now Underwriters Laboratories Approved . . . the "707" Series for Class I, Group D hazardous locations . . . and the "709" Series for Class I, Group C as well as Class II, Groups E, F and G.

The "707" Series Brakes are built to withstand an internal explosion within U.L. limiting requirements. The "709" Series meets explosion requirements, and also includes a thermal release to automatically release the brake if the housing temperature approaches the limits set by U.L. as dangerous for possible ignition of various dusts, etc.

IMPORTANT FEATURES

- Direct Acting mechanism assures fast response, positive action and elimination of troublesome linkages.
- Automatic reset manual release as standard equipment.
- "Fail Safe" mechanism; brake sets in the event of power failure.
- Wide range of torque ratings.
- Motor mounts on standard NEMA "C" end shield.
- Standard motor shaft extensions are used; no special brake shaft required.

The new Dings "700" Series Brakes can be supplied for motor mounting or for foot mounting. Specify Dings Brakes from your regular motor supplier . . . or ask about Dings complete engineering service for your brake problems.

DB356½

Write for Bulletin BK 4707

DINGS BRAKES, INC.
A SUBSIDIARY OF DINGS MAGNETIC SEPARATOR CO.
4714 West Electric Avenue
Milwaukee 46, Wisconsin

Circle 594 on page 19

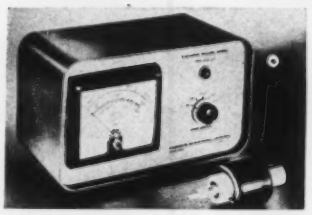
ENGINEERING DEPARTMENT

EQUIPMENT

Vacuum Gage

has pressure range from 25 microns to 1 x 10^{-7} mm Hg

Single-station, discharge-type vacuum gage gives continuous pressure readings over range from 25 microns to 1 x 10^{-7} mm Hg. Instrument has low-current sensing tube, printed circuitry, automatic voltage regulation and terminals for



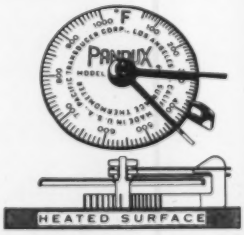
driving a potentiometer-type recorder. Unit measures total pressure of condensable vapors and permanent gases on three scales. It measures 6 ½ in. high, 11 in. wide, 6 in. deep, and weighs 12 lb. Power required is 115 v, but unit is adaptable to 230 v. **Consolidated Electrodynamics Corp.**, Rochester Div., 1775 Mount Read Blvd., Rochester 3, N. Y.

Circle 473 on page 19

Thermometer

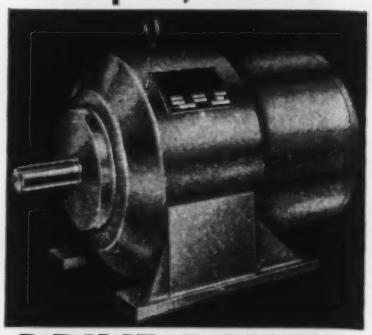
has a range of 50 to 1000 F

Maximum-minimum surface temperature thermometer has two auxiliary pointers showing maxi-



mum and minimum excursions of the thermometer over any period of time. Temperature range is 50

Compact, Efficient



DRIVE POWER with the Philadelphia GEARMOTOR

These modern GearMotoRs offer the simplest, most reliable and compact machinery drives obtainable . . . featuring real economy in lowered original cost, and reduced maintenance through long years of trouble-free service. Philadelphia GearMotoRs are extremely compact and efficient. They are highly resistant to moisture, chemical fumes and abrasive dusts . . . Helical gearing with crown-shaved teeth assures ultra-fine surface finish, controlled contact at center of teeth, plus long, silent service life . . . Two-way seals lock-in oil and lock-out dirt . . . Heavy shafting of heat treated alloy steel eliminates bending or twisting under heavy loads . . . Oversize thrust bearings can handle big overhung loads . . . gear units and integral motors conform to AGMA and NEMA Standards.

Be convinced, send for Catalog GM-560 which fully describes and illustrates the new Philadelphia GearMotoRs, Utility type GearMotoRs, In-Line Reducers, and Motorized Worm Gear Drives.

UNIT TYPE	MODEL	H. P.	RATIO
SINGLE REDUCTION		1-60	1.25:1 to 5.06:1
DOUBLE REDUCTION		1-60	6.20:1 to 31.4:1
TRIPLE REDUCTION		1-40	38.5:1 to 158.9:1

phillie gear®
PHILADELPHIA GEAR WORKS, INC.
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INDUSTRIAL GEARS & SPEED REDUCERS
LIMITORQUE VALVE CONTROLS
FLUID MIXERS • FLEXIBLE COUPLINGS
Virginia Gear & Machine Corp. • Lynchburg, Va.

Circle 595 on page 19

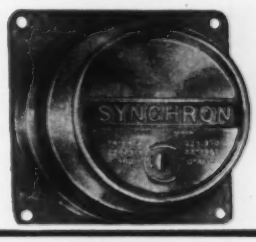
THE POWER-RATED SYNCHRON LINE / A TIMING MOTOR FOR EVERY JOB

8 IN. OZ. TIMING MOTOR

Widely used in timing machines, time switches, heating and air conditioning controls, action signs, recording thermometers, and other timing devices. Guaranteed to pull 8 in. oz. direct load continuously at 1 r.p.m.

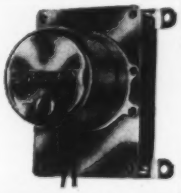
20 IN. OZ. TIMING MOTOR

Ideal for timing motor applications requiring continuous high torque power. Instant starting, dependable accuracy, and flexible installation. Call for Synchron's guaranteed 20 in. oz. at 1 r.p.m. power when your job calls for long, continuous torque.



1 R.P.H. TIMING MOTOR

Guaranteed to pull 20 in. oz. at 1 r.p.h. (1/60 r.p.m.) Synchron's especially developed motor for slow motion timing applications. Eliminates need for extra reduction gears between 1 r.p.m. and 1 r.p.h. in intermittent time trains. Gives gear train with lifetime lubrication; enclosed and trouble-free.



SYNCHRON TIMING MACHINES

An almost unlimited number of shaft speeds. Synchron Motor fixed to a rigid frame. Easy to mount and connect in any position. Trouble-free, accurate. Drives everything from liquid recorders to program clocks and washing machine timers. Highlights complete versatility of famed Synchron Line.

SYNCHRON CLOCK MOVEMENTS

For standard and office clocks, sign clocks, novelty clocks, and clocks of all kinds up to 26" in diameter under glass. Split-second accuracy and long wearing construction, never needs oiling. Furnished with front, rear or bottom set, with or without dustproof case.

MAGNA-TORC D.C. MOTOR

Designed originally for use in aircraft instruments and radio control mechanisms. During World War Two the Hansen Magna-Torc proved its rugged dependability in all altitudes and in all climatic conditions. Now this motor is being adapted to many commercial applications.

"Workhorse of the industry"

*Synchron synchronous motors operate smoothly, evenly in any position; at temperatures from —40° to +140°F.; start instantly under load; pull up to 20 in. oz. at 1 RPM. Available in 42 speeds from 0.8 RPM to 600 RPM.

Synchron timing motors in all speeds available for prompt delivery

SYNCHRON®

SYNCHRONOUS MOTORS, TIMING MACHINES, CLOCK MOVEMENTS, MAGNATORC D.C. MOTORS

HANSEN MFG. CO., INC.

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Princeton 12, Indiana

FACTORY REPRESENTATIVES: The Fromm Co., 5254 W. Madison St., Chicago, Ill. • R. H. Winslow Assoc., 123 E. 37th St., New York, N.Y. • Electric Motor Engineering, Inc., 8255 Beverly Blvd., Los Angeles 48, Cal. and 3907 Lyon Ave., Oakland, Cal. •H. C. Johnson Agencies, Inc., Rochester, Buffalo, Syracuse, Binghamton, N.Y.

design data

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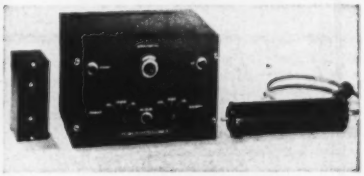
to 1000 F. An Alnico magnet is provided for attachment to ferrous surfaces when the thermometer is used vertically. Calibration is accurate to within ±2 per cent, and the unit can be recalibrated when necessary. Diameter is 1¾ in.; unit weight is ½-oz. **Pacific Transducer Corp.**, 11836 W. Pico Blvd., Los Angeles 64, Calif.

Circle 474 on page 19

Power Positioner

high-speed unit has large torque capacity

Power positioner for remote positioning systems features torque capacity independent of error-signal magnitude, high speed operation without overshoot or oscilla-



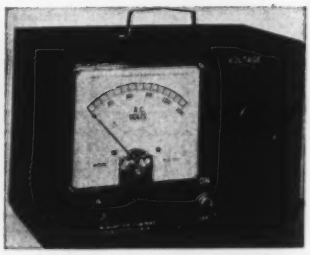
tion and small size actuator with high torque capacity. Unit has excellent positioning accuracy with low dead band and operates on 115 v ac, 60 cycle current. **Globe Industries, Inc.**, 1784 Stanley Avenue, Dayton 4, Ohio.

Circle 475 on page 19

Power Supply

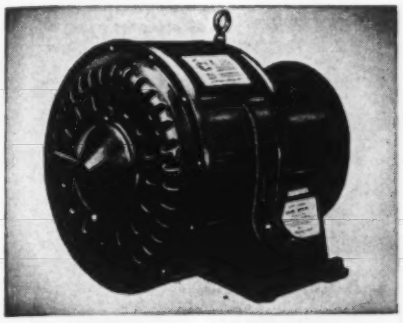
provides infinitely variable output

AC power supply features a fuse-protected variable auto-transformer, neon pilot light and 4½ in. volt-

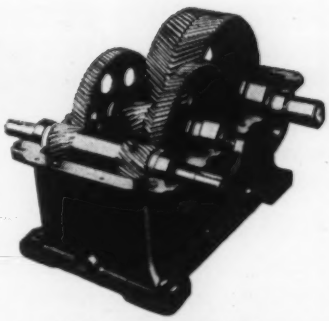


meter with essentially linear scale. Nominal input is 115 v, 60 cycles; output rating is 3 amp; voltage is infinitely variable from 0 to 135. **Slaughter Co.**, Piqua, Ohio.

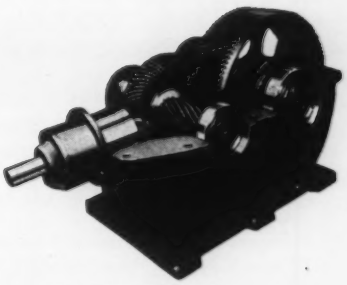
Circle 476 on page 19



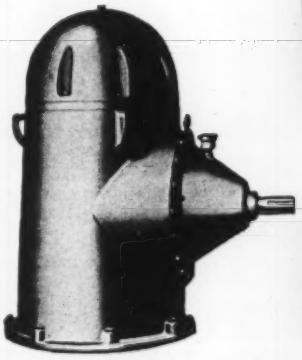
Western Gear Torq-Master Transmission, for use with torque converters



Herringbone gear speed reducer



Right angle speed reducer



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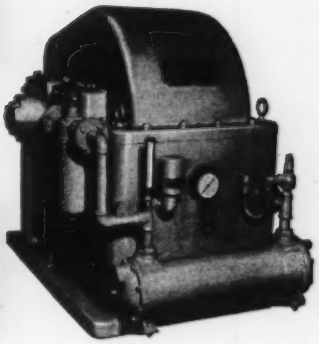
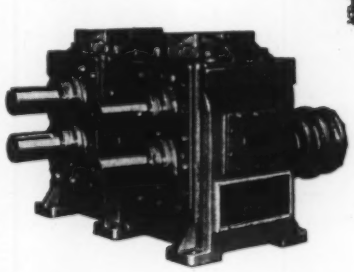
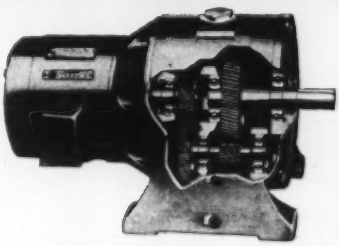


High speed unit



Western Gear Pinion Stands for rolling mill drives



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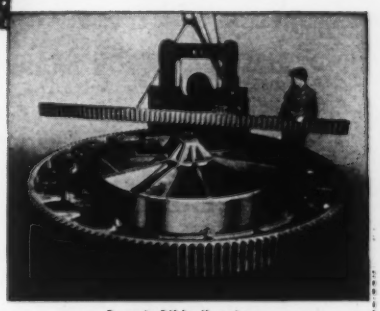

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Industrial Engineering Handbook. *Edited by H. B. Maynard, president, Methods Engineering Council, Pittsburgh, Pa.;* 1504 *pages, 6 by 9 in., clothbound; published by McGraw-Hill Book Co. Inc.,* 330 *W. 42nd St., New York* 36, *N. Y.; available from* MACHINE DESIGN, $17.50 *postpaid.*

This handbook presents a treatment of the entire field of industrial engineering, including its development and function, its place in management and its organization. Also discussed are methods, motion-time analysis, wage administration, production costs, quality control, product design, estimating, cost-reduction procedures and research.

New Standards

Design for Fine-Pitch Wormgearing, AGMA 374.03, ASA B6.9-1956. 20 *pages,* 8½ *by* 11 *in., paperbound; published by and available from American Society of Mechanical Engineers,* 29 *W. 39th St., New York* 18. *N. Y.,* $1.50 *per copy.*

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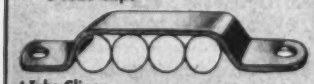

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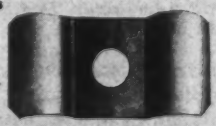

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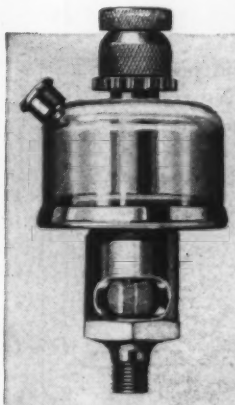

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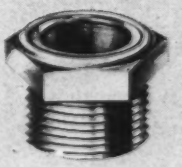

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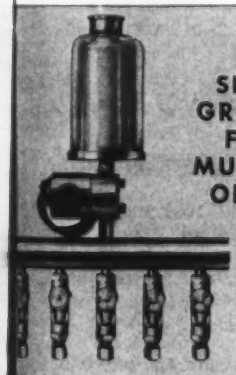

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Circle 599 on page 19

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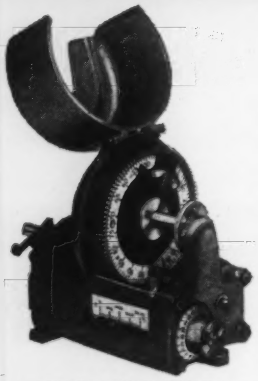

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CYCLO-MONITOR

COUNTS: Shaft Revolutions
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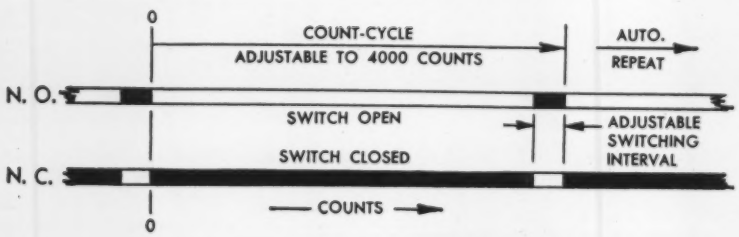

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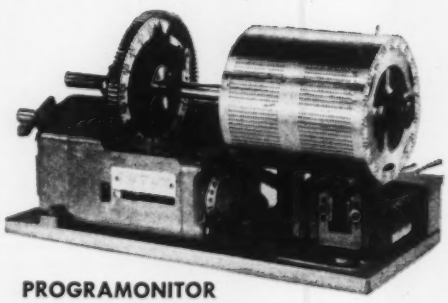

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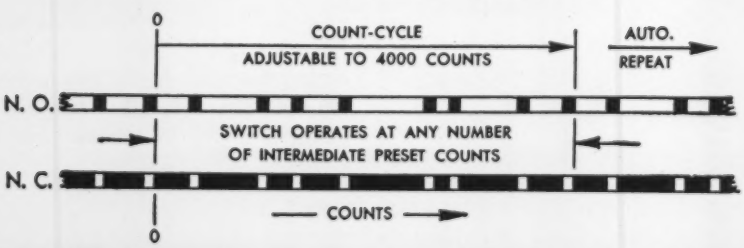

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to 30.0 degree worm lead angle range. The standard is set up to provide geometric similarity of tooth form within the pitches and lead angles covered. Simplification of design is obtained by standardizing on a minimum number of symmetrical double-conical tooth-form cutters and a minimum of simplified, standard blank designs.

Association Publications

Bibliography of Hardness and Hardness Testing from 1937 to 1955. *118 pages, 7 by 10 in., paperbound, side-stapled; published by and available from Industrial Diamond Information Bureau, London, E.C.*1; *5s 6d per copy.*

This booklet gives a complete bibliography on all branches and aspects of hardness, hardness testing methods, and research work in which hardness testing was used as one method of an investigation.

Manufacturers' Publications

Tool Steel Handbook, 4th Edition. *204 pages, 8½ by 11 in., clothbound; published by and available on letterhead request from Allegheny Ludlum Steel Corp., Advertising Dept., 2020 Oliver Bldg., Pittsburgh 22, Pa.*

The enlarged and modernized fourth edition, like its predecessors, contains complete data on types, properties and applications of tool steels. The revised book devotes chapters to selection of the proper steel, tool steel products, working of tool and high speed steels, heat treating information, and reference tables.

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Government Publications

Proceedings of the 1956 Electronic Components Symposium. *240 pages, 8½ by 11 in., paperbound; published by and available from Engineering Publishers, GPO Box 1151, New York 1, N. Y.; $5.00 per copy.*

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Circle 601 on page 19

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Fundamentals of Brazing. PB 111697. *By N. Bredzs and O. T. Barnett, both of Armour Research Foundation, Illinois Institute of Technology; 151 pages, 8 by 10½ in., paperbound, side-stapled; available from Office of Technical Services, U. S. Dept. of Commerce, Washington 25, D. C.; $4.25 per copy.*

This book reports on investigation of causes of imperfections in brazed joints and factors determining the strength of such joints; the book also discusses wetting of the base metal by the filler metal and the influence of oxygen diffusion through layers of molten filler metals upon the wettability. The investigation of the tensile-strength joint-thickness relationship is of both practical and theoretical interest.

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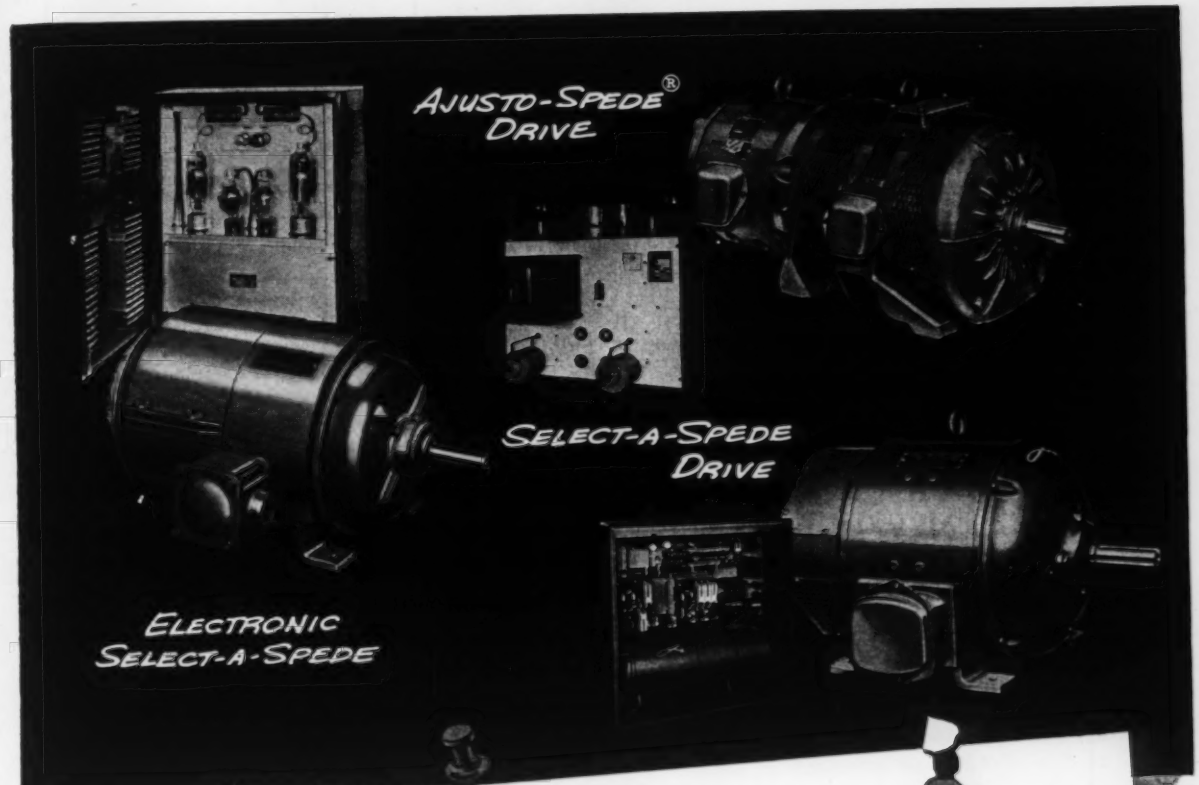

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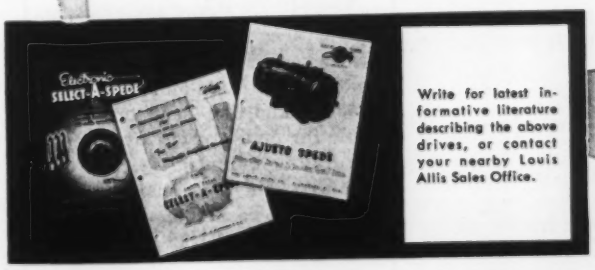

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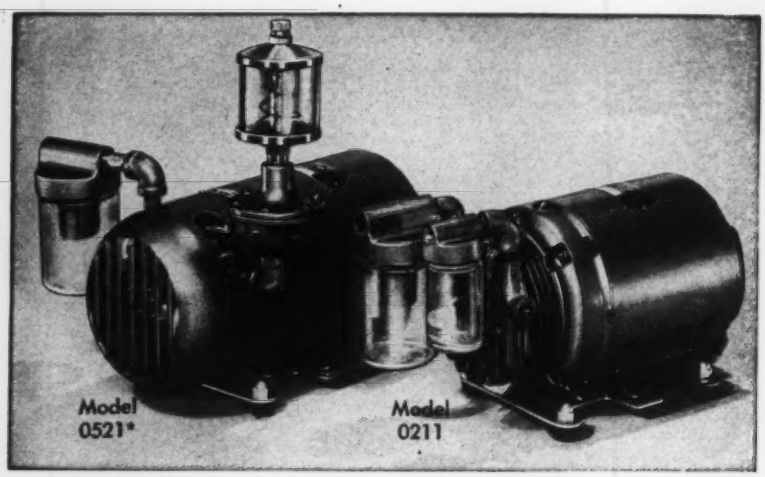
Circle 602 on page 19



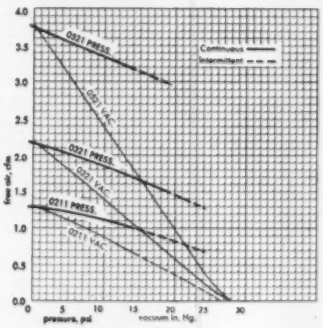
Get 10 Integral-Motor-Pump advantages in two NEW types (three models) of

GAST rotary vane AIR PUMPS

Designers seeking a dependable vacuum or pressure source for industrial instruments, vending machines, air gauge circuits, air sampling, laboratory equipment, printing and packaging machinery, etc., will find these *new* Gast Integral-Motor Air Pumps highly advantageous, especially where compactness and portability count. Consider these outstanding features:

1. Latest type G.E. "Form G" motors.
2. More compact than any pump of equal capacity.
3. Total weight reduced ⅓—cuts shipping costs.
4. Motor mounting time and labor eliminated.
5. Simple, trouble-free rotary-vane design.
6. Vanes take up their own wear automatically.
7. Positive displacement, pulseless air delivery.
8. Improved appearance—smoother exterior.
9. Dependable for original equipment; plant use.
10. Forced air fan cooling on Models 0321 & 0521.

Performance-Vacuum & Pressure



Write for new Bulletins V-356 and P-356!
GAST MANUFACTURING CORP.,
P. O. Box 117-P, Benton Harbor, Mich.

*0321 similar in appearance.

Original Equipment Manufacturers for Over 25 Years

GAST ROTARY

- AIR MOTORS TO 4 H.P.
- COMPRESSORS TO 30 P.S.I.
- VACUUM PUMPS TO 28 IN.

SEE OUR CATALOG IN SWEET'S PRODUCT DESIGN FILE

New Machines

Metalworking

Grinders: Type C-2 14-in. and LC-2 18-in. cylindrical grinding machines handle workpieces weighing up to 6500 lb. Controls for feeds and speeds are located on the front of the machine. Combination graduated wheel-feed handwheel and indexing mechanism indicates the amount of infeed as the wheel rotates past a fixed pointer and permits settings in increments of 0.0001-in. work diameter reduction without visual attention. Table speeds for truing and grinding are independently adjustable and preset. Table drive by hydraulic power is available from 2 to 240 in. per minute. Metal-to-metal contact in all feeding mechanisms produces fast spark-out. Electrical controls are located in an elevated enclosure for convenient inspection. Both machines are available as plain grinders or as semiautomatics. *Norton Co., Worcester, Mass.*

Depth and Contour Mills: Two new mills, designed for cutting airframe parts, have a high-speed spindle and cutter which rout difficult contours and mill complex aluminum shapes such as wing panels, slugs, doors, frames, ribs, spars and stiffeners to different depths. Basic machine consists of a heavy base with a jointed radial arm. At the end of the arm is mounted a direct-drive cutter motor available with adjustable speeds from 3600 to 14,000 rpm. T-slotted table under the arm holds the aluminum slab. Model 480 has a maximum arm extension of 120 in. from column center to spindle center and 60 x 120-in. work table. Model 484 has a maximum arm reach of 60 in. and a work table 30 x 60 in. Cutter motor is slide-mounted, water-cooled and independently adjustable for depth of cut by a separate hydraulic cylinder. Other design features include mist lubrication to motor bearings, double slides, and four-position depth stops with

micrometer adjustments. Depth cutting performance is accurate to 0.005-in. *Ekstrom, Carlson & Co., Rockford, Ill.*

Processing

Ultrasonic Cleaner: Model AP-10-B ultrasonic cleaning apparatus is designed specifically for bench-top operation in the washing of delicate and intricate parts such as watch mechanisms, instrument components, small and miniature ball bearings, electronic parts and so forth. The unit comprises a 36-40 kc/sec power generator and a cylindrical cleaning tank, with transducers hermetically sealed into the base. Power output of the generator is 50 w average, 200 w peak on pulses. Tanks are of 1 pt, 1 qt or ½-gal capacity, giving a maximum effective cleaning area of 18 sq in. Two of the smaller tanks can be operated simultaneously and two of the larger tanks alternately, depending on tank size specified. Cleaning action reaches blind holes and complex geometry. *Branson Ultrasonic Corp., Stamford, Conn.*

Foil Press: No. 21½-F press with 50-ton capacity is designed for the production of aluminum foil products such as pie plates and cake plates. Precision-type single roll feed mounted between the uprights takes foil directly from the coil and feeds it forward across the die area. Feed rolls are 24½ in. wide and maximum feed length is 18 in., permitting a wide range of both large single-die work or smaller multiple-die work. Variable-speed drive gives an operating range of 60 to 120 strokes per minute. All adjustments to the press can be made from floor level. *E. W. Bliss Co., Canton, O.*

Hydraulic Presses: New 30 and 50-ton hydraulic presses are used for rubber and plastic molding, testing, and for laminating, either on a production or laboratory basis. They contain a 5-in. ram with 5-in. stroke, and develop up to 60,000 and 100,000 lb pressure respectively on the platens. Platens are precision ground and are available in 12½ x 12½ and 12½ x 18½ in. sizes. Cast-in heaters, operating on 220 v ac, permit heating up to

Originality and economy are compatible . . . at ARWOOD

INVESTMENT CASTING is one of the few production processes that caters to the creativeness of a design engineer. No more frustration caused by the limitations of conventional processes. And . . . without sacrificing production economy, either!

If application requirements demand that a part be of intricate shape and unusual contour, of metals difficult or impossible to machine, INVESTMENT CASTING provides the efficient and economical solution to your design and production problems.

CASE IN POINT

FREEDOM OF DESIGN. This steel hinge was formerly a complicated assembly composed of a stamped bracket and machined hinge welded together. With investment casting the engineer was able to design the part for utmost efficiency as a single piece with substantial savings in production costs.

A New Service for YOU!

ARWOOD offers a complete finish-machining service, for your convenience. All Arwood plants can now furnish finish-machined castings to your specifications.

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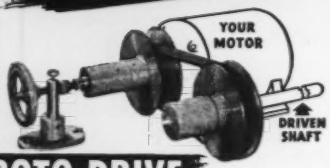
"PIONEERS IN INVESTMENT CASTING"

Circle 604 on page 19

...for infinitely
VARIABLE SPEED
From Fractional to 20 Horsepower
For old or new NEMA Motors



ROTO-DRIVE

Speed variation up to 8 to 1.
Mounts in any position.
No adjustable motor base.
Operates on fixed centers.
LOW COST—Saves 40% compared with conventional motordrives.

ROTO-CONE

Offers up to 4 to 1 speed variation.
V to V drive.
Exclusive design permits V-belt to travel on fixed center line.
Easily installed. HP ranges fractional through 20.

VAR'A'CONE

For fractional HP requirements. Uses "A"-section V-belt.

Up to 2¾ to 1 speed ratios.
List price low as $5.40. 3 sizes.
An efficient and low cost method of adding variable speed.

Complete selection standard variable speed belts, standard and countershaft adjustable motor bases, companion sheaves, and flexible couplings.

Write for 30-page Catalog

Gerbing MFG. CORP.
Dept. M56
Northbrook, Ill.
(A Suburb of Chicago)

Circle 605 on page 19

New Machines

600 F. Temperature, controlled by individual adjustable thermoswitches, is indicated by thermometers on the front edge of each platen. Platens contain coils for water cooling and can be adapted for steam heating. Each platen has its electrical components mounted on a separate chassis inside the cabinet. They are easily accessible through a hinged door. Space between columns measures 13¼ in., permitting the use of large molds and dies. Models are available with single and multiple openings. *Kingsbacher-Murphy Co., Hydraulic Div., Hollywood, Calif.*

Testing and Inspection

Surface Finish Tester: Surface finish testing and measuring instrument measures all standard surface finish designations. The values, either in microns or microinches, are computed electronically as the tracer scans the surface. An absolute measurement is obtained. Unit measures plane or curved surfaces, internal and external diameters and tapers, arbor holes ½-in. in diameter and larger. Apparatus consists of a measuring head which contains the electrical feeler system, feed mechanism and the components for conversion of the electronic values into surface index standards; a measuring stand to accommodate the measuring head and workpiece; an electric amplifier and a profile recorder for a permanent record of the surface finish. *William J. Hacker & Co. Inc., New York.*

Lubricant Testing Machine: Model LFW-1 testing machine for lubricants tests both bonded coatings and liquid lubricants. A stationary rectangular block is pressed with a predetermined load against a rotating ring. Resulting friction is indicated throughout the test by a dial indicator, and a counter counts the number of revolutions of the specimen. Tests are based on either the reaching of a preselected friction maximum or the reaching of a preselected temperature value. *Alpha Molykote Corp., Stamford, Conn.*

The TIMER RELAY that eliminates controlled timing problems

★ No false contacts
★ Non sticking
★ Practically "fail safe"
★ Low cost timer

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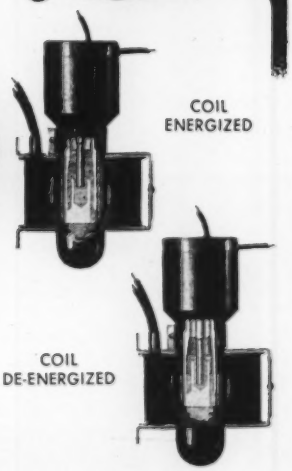
Durakool
STEEL MERCURY TIMERS



This steel clad, factory set, tamper proof Durakool timer-relay is practically non-breakable. Operating life multiplied 5 to 6 times by new plunger construction features. Any combination of operate-release time delays from 0.15 sec. to 20 sec.—either normally open or normally closed action.

See telephone directory for local distributor, or write.
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700 WESTON RD. TORONTO 9, CANADA

Send for Bulletin 800

Circle 606 on page 19

Koppers 2-Piece Sealing Rings are installed on hot air shut-off valves manufactured for aircraft by Hydro-Aire, Inc. Ring inners are of stainless steel . . . ring outers are made of high chrome alloy heat resistant cast iron. Diameter is 1¼"

Koppers 2-Piece Rings Solve High Temperature Sealing Problems for Hydro-Aire

A Product of Continuous Research and Development by KOPPERS

To solve a sealing problem at high temperatures, Koppers engineers created a new sealing ring for Hydro-Aire, Inc.

Hydro-Aire, Inc. . . . a subsidiary of Crane Co. . . . manufactures hot air shut-off valves for aircraft applications. Ordinary rubber "O" rings couldn't withstand the high temperatures involved.

Koppers engineers designed a 2-Piece Sealing Ring with extremely close tolerances that provides maximum sealing at high temperatures. Primarily designed for aircraft applications, this new type ring can be used for sealing fuel oil and hydraulic oils as well as hot air and other gases.

The Hydro-Aire application is an interesting example of how highly trained Koppers engineers can solve customers' sealing problems. Koppers engineers in your area will be glad to study your applications and design the proper type of ring.

KOPPERS®

To lower your production costs, bring your ring problems to Koppers. Write to KOPPERS COMPANY, INC., 2311 Hamburg Street, Baltimore 3, Maryland.

RING-TYPE SEALS

Koppers Company, Inc., Metal Products Division
Piston Ring and Seal Department

Engineered* Products Sold with *Service

WANTED

Technical Editor

Here is a real challenge for the right man with enthusiasm for writing and a strong creative urge to broaden his perspective and assist industry in effectively applying the techniques of automation.

Edited by a competent staff of experienced engineers, AUTOMATION has an opening for an engineer with diversified manufacturing or production equipment design background and editorial or other writing experience. He should be able to write well, be familiar with automation engineering and have evidence of same.

Duties include development, writing, editing articles and feature departments.

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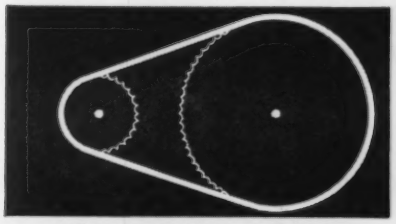
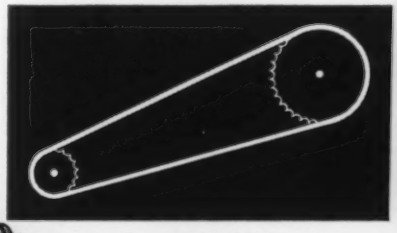
Headquarters in Cleveland, Ohio.

If you are interested and feel qualified, please send full details of your practical engineering and writing experience to the Editor, AUTOMATION, Penton Building, Cleveland 13, Ohio.

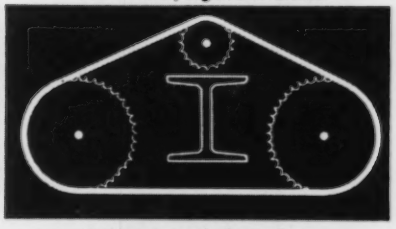
VERSATILE DIAMOND CHAINS SOLVE MANY DRIVE PROBLEMS AT LOW COST...



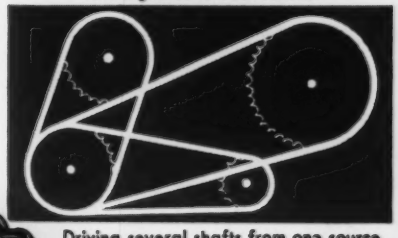
Short center, high ratio drives



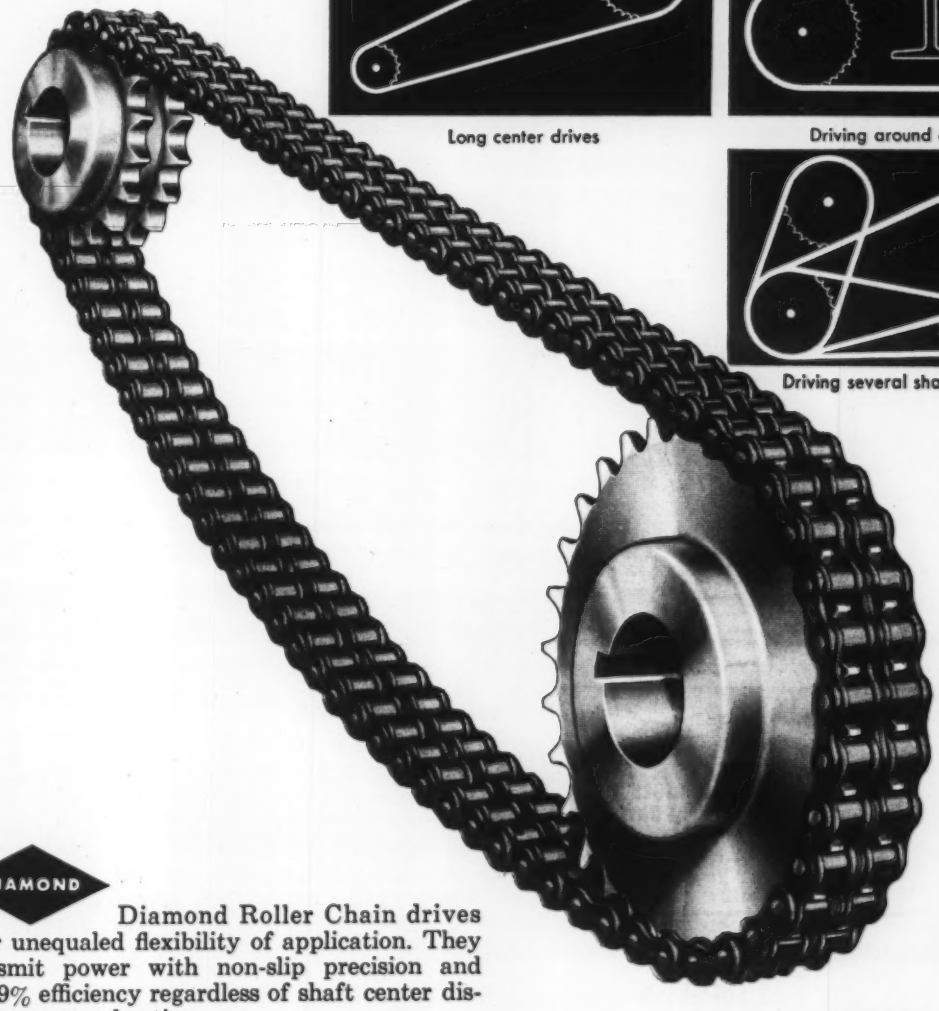
Long center drives



Driving around obstructions



Driving several shafts from one source



DIAMOND

Diamond Roller Chain drives offer unequaled flexibility of application. They transmit power with non-slip precision and 98-99% efficiency regardless of shaft center distances or speed ratios.

Obstacles in the drive path are easily avoided. Diamond Roller Chain's light weight and compactness allow lighter machinery construction, eliminate power consuming gear trains and the many shafts and bearings they require.

Diamond Engineers are available now to help you solve your drive problems. Write or call today.

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Dept. 435, 402 Kentucky Ave., Indianapolis 7, Indiana
Offices and Distributors in all Principal Cities

DIAMOND ROLLER CHAINS

Where High Quality is Traditional

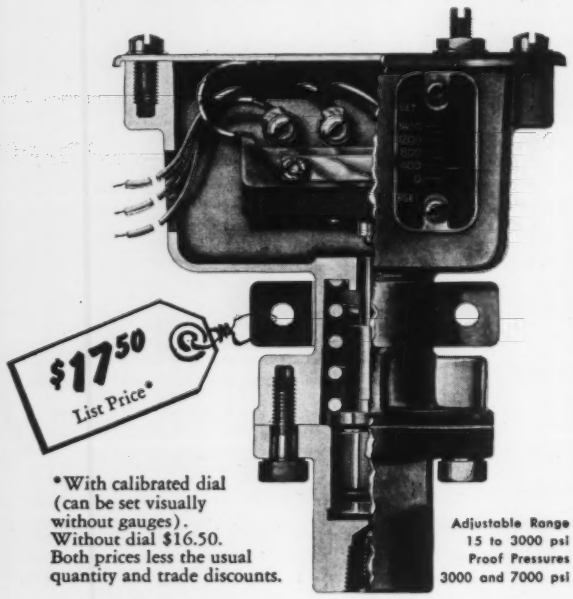
If you build

PRODUCTION EQUIPMENT

compare this pressure switch

for ***RUGGEDNESS,***

DEPENDABILITY and COST



*With calibrated dial (can be set visually without gauges). Without dial $16.50. Both prices less the usual quantity and trade discounts.

Adjustable Range 15 to 3000 psi
Proof Pressures 3000 and 7000 psi

WE BUILD IN	WE DON'T USE
RUGGEDNESS Can take surges—(High proof pressures) Continuous operation—(Millions of cycles) No sticking—(in dirty fluid)	**LINKAGES & BEARINGS** Which wear quickly—(cause settings to drift and switch to fail).
LABOR & MATERIAL SAVINGS No return drain piping—(Sealed piston) Mounts where convenient (Operates in any position, Not sensitive to vibration)	**UNSEALED PISTONS** Which add to your installation cost (return piping). Are critical to dirt—(pistons get stuck).

BARKSDALE VALVES

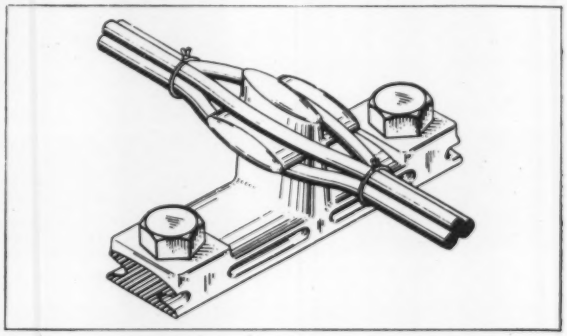
PRESSURE SWITCH DIVISION
5125 Alcoa Avenue, Los Angeles 58, California

Ask for bulletins 9612 and C9612.

NOTEWORTHY Patents

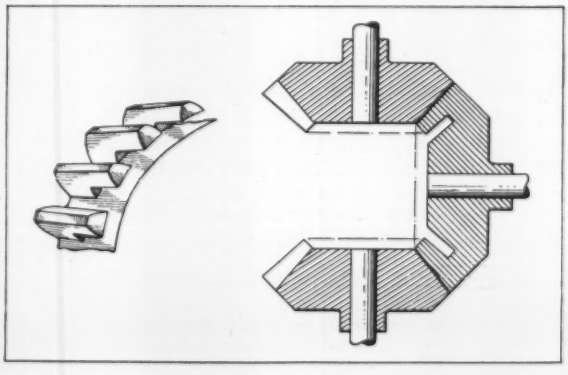
Wire Holder

Bundled electrical conductors, such as those that make up aircraft electrical-system harnesses, are supported and held out of contact with adjacent structural members by a wire holder of cruciform shape. Made of insulating material, the holder minimizes possibilities of wire chafing or grounding in long-run, multiwire installations. No special tools are needed for installation of the device, and testing or replacement of individual wires can be carried out without necessity for disassembly. *Patent* 2,764,626 *assigned to Boeing Airplane Co. by Harold F. Teichroew.*

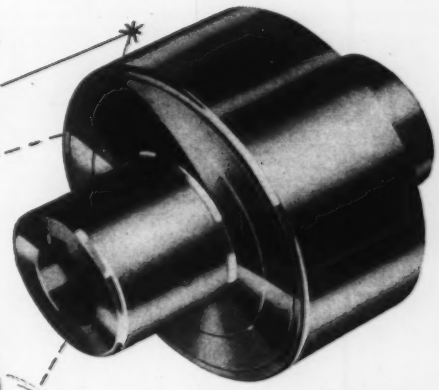


Antibacklash Gears

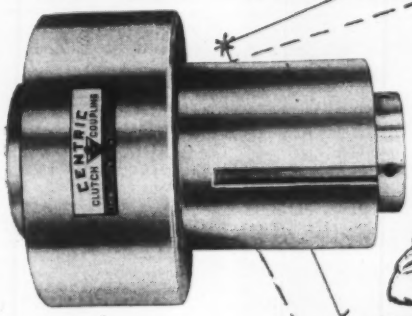
Lost motion or free play in precision spur, helical or bevel-gear trains is eliminated by an undercut-tooth configuration in an antibacklash gear design. Flexing of the free ends of the teeth, which have their flanks skewed at a slight angle to the gear axis, effectively preloads the gear train when the antibacklash gear meshes conventional gears. Besides taking up backlash, the unit cushions shock that may be transmitted through the gear train. Friction intro-



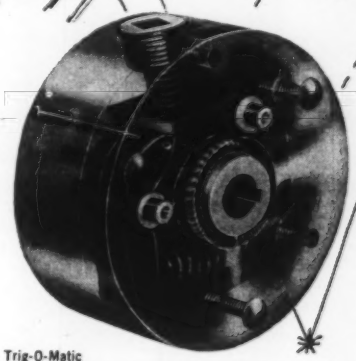
Why designers prefer "CENTRICS" for any type power drive



Type A Clutch-Coupling for direct (motor) drives



One of the complete line of Type B Clutches for indirect drives



The new Trig-O-Matic Overload Release Clutch

For Direct (Motor) Drives

Type A Clutch-Couplings

Capacities—fractional to 2500 H.P.

For Engine and Dual Drives

Type A Spring Control Clutch-Couplings

Capacities—fractional to 2500 H.P.

Type AVL Vertical Lift-Out Clutch-Couplings

Capacities 5 to 1500 H.P.

For Indirect Drives

Type B Clutches

Six basic models to fit standard pulleys, "V" belt, sheaves and sprockets for motors, engines and dual drives.

Prevent Overloads

Trig-O-Matic Overload Release Clutch

provides positive torque limit without any wearing parts. Lock-out design provides complete disengagement.

CENTRIC CENTRIFUGAL CLUTCHES AND CLUTCH-COUPLINGS

meet every power drive need in—

Design • Construction • Performance

—and there's a complete range of Centric models for every type of drive.

Design Simplicity means a minimum of working parts for a long trouble-free life.

Controlled Fabrication—Every part and the working components meet our high standards of accuracy and close tolerances.

Performance—In every case, where Centrics have been installed, operation and performance have measured up to complete satisfaction for—

Smooth Cushion Starts • Acceleration Control • Overload Protection

Illustrated bulletins are available—a separate bulletin for each type of Centric Clutch and Clutch-Coupling. Complete details are given covering operation, sizes and ratings. *Send for your copy.*

What is your drive problem? May we help solve it

CENTRIC *Clutch Company*

P. O. BOX 175 • U. S. ROUTE 9 AT MAIN STREET • WOODBRIDGE, NEW JERSEY

Circle 610 on page 19

Here are a few parts turned out on high-speed multiple-spindle automatic screw machines in quantity. Some are complete as they drop from the machine.

Others require additional finishing operations, like the largest piece, a special 10-32 collar screw with head formed and flattened on a punch press, *triple-lead* roll-threaded and then copper plated.

Your requirements may be for smaller or larger pieces. Western's capacity ranges from 1/16 to 4¾" round, with *all* necessary finishing equipment for such secondary operations as milling, drilling, threading, tapping, heat-treating and grinding.

For fast, reliable delivery, precision quality and low cost, it pays you to put WESTERN on your production team.

Why not send us your blueprints for quotations . . . today?

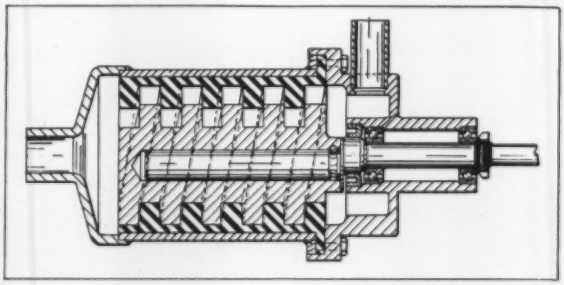
The Western Automatic
Machine Screw Company
division of Standard Screw Company
383 Woodland Ave., Elyria, Ohio
Precision Parts and Assemblies Since 1873

Noteworthy Patents

duced is slight, making the gear particularly applicable to computer, instrument, and indicating devices. *Patent* 2,764,034 *assigned to Specialties Inc. by William Hotine.*

Screw-Type Pump

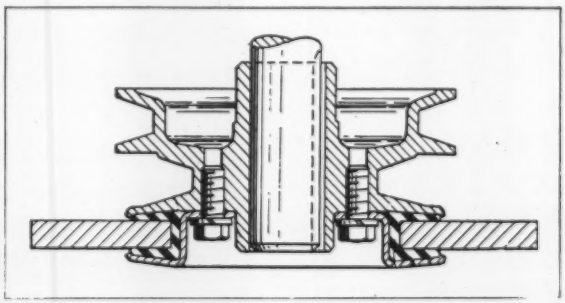
Pumping action in a screw-type pump is generated by eccentric motion of the rotor axis about the fixed stator axis, rather than by pure rotation of the rotor. Progressive mating of external and internal square



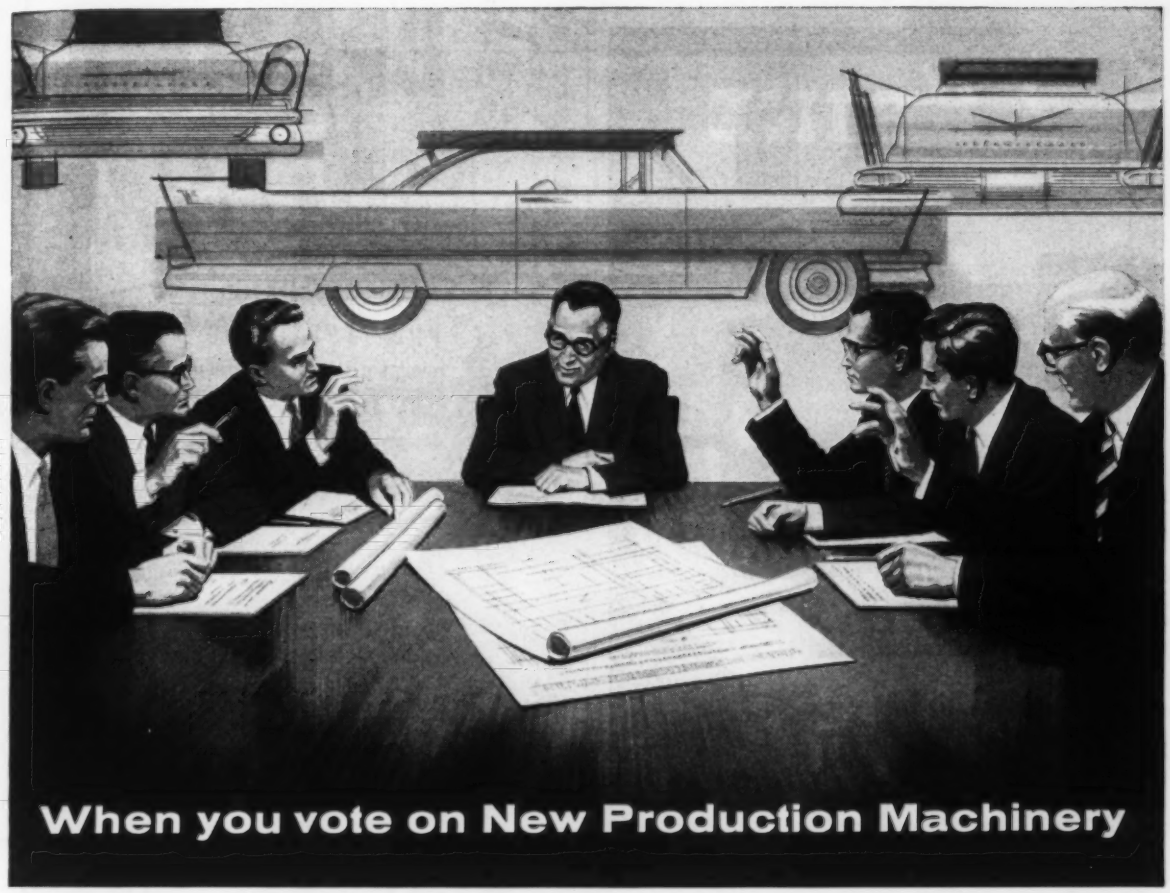
threads on the rotor and stator surfaces forces fluid along the pump axis from inlet (left) to outlet (right). Effective thread-to-thread sealing of the unit requires that either rotor or stator be natural or synthetic rubber. Sizable solids can therefore be passed through the pump along with the liquid without damage. Unit can pump liquids, air or gases, or will function as a vacuum pump. *Patent* 2,764,101 *assigned to Rand Development Co. by Henry J. Rand.*

Torsional Vibration Damper

Resonant shaft vibrations of the type encountered in internal-combustion engine crankshafts, as well as nonresonant torsional vibrations over a substantial rotational-speed range, are suppressed by a tuned, torsional vibration damper. Shown here in a combined



pulley-damper design, the unit employs a disk-shaped inertial mass mounted in a prestressed rubber ring as its damping element. Construction permits use of relatively hard rubber in the mounting ring, giving increased hysteresis and improved durability. Natural frequency of the damper varies from 30 to 60 per cent of engine frequency. *Patent* 2,764,038 *assigned to H. A. King Co. by Thomas H. Peirce and James B. Robinson.*



...do you vote a straight AMERICAN ticket?

There's no real substitute for American-made production machinery in any branch of American industry. Designed and built to take the strains and stresses of the world's toughest demands for speed and endurance . . . with a minimum of down-time and maintenance . . . American machines are today more than ever the best buy in every field from textiles to metal-working. Yes, American production machines are the backbone of America's competitive economy . . . *and why settle for anything else?*

VEEDER-ROOT INC.

"The Name that Counts"

Hartford, Conn. • Greenville, S. C. • Chicago
New York • Los Angeles • San Francisco • Montreal
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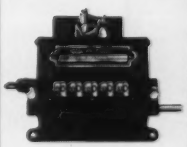
. . . and here's why it pays to make sure that All New Machines you buy are equipped with NEW VEEDER-ROOT COUNTERS...

Modern Veeder-Root Counters are available for *building into* . . . or attaching onto . . . all types of production machines. They are built with unmatched Veeder-Root know-how and quality for years of accurate Countrol of production and uniformity. Ask your Industrial Supply Distributor or write Veeder-Root Inc., Hartford 2, Conn.

Hand Counting: Vary-Tally Multiple Unit Reset Counters for inventory, inspection and 1,001 hand-counting jobs. Up to 108 counters in 1 bank.

Mechanical Counting: Small resets count strokes, turns, pieces . . . are built into machine tools, light presses, etc.

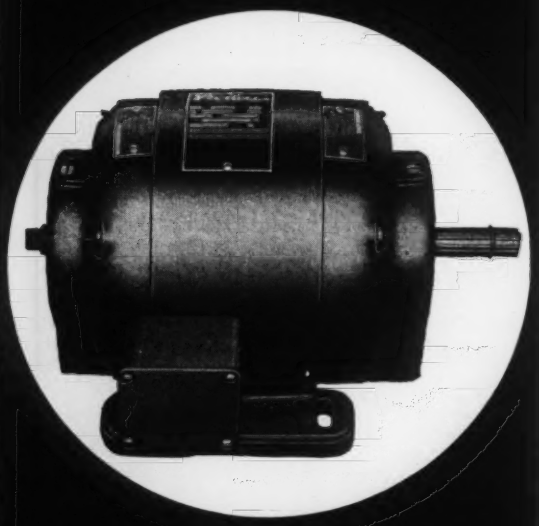
Electrical Counting: Remote indicating counters (AC or DC) bring your production machines as close as your office wall. May be panel-mounted in groups.



Controlling: Set for number of turns, pieces or operations required. Predetermining Counters control the run exactly . . . prevent over-runs and shortages.

Circle 612 on page 19

MARINE



DUTY

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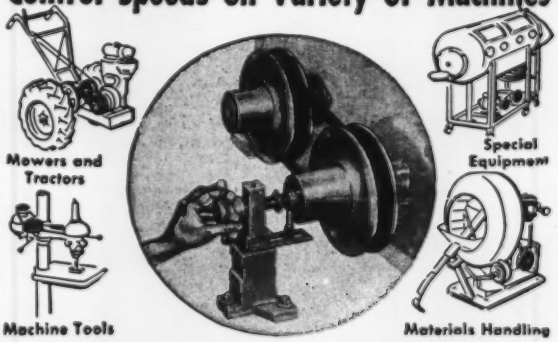

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Circle 613 on page 19

Circle 615 on page 19

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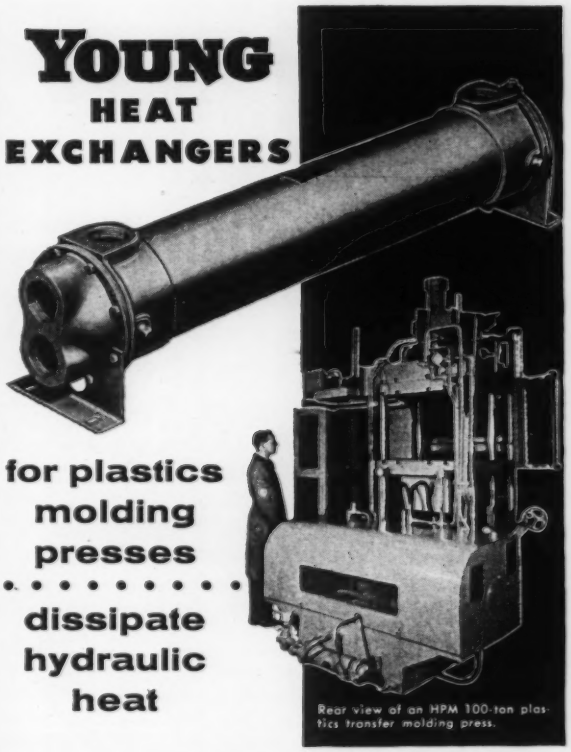

for plastics molding presses

dissipate hydraulic heat

Rear view of an HPM 100-ton plastics transfer molding press.

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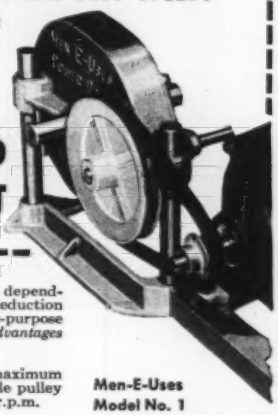

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Circle 619 on page 19

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Circle 620 on page 19

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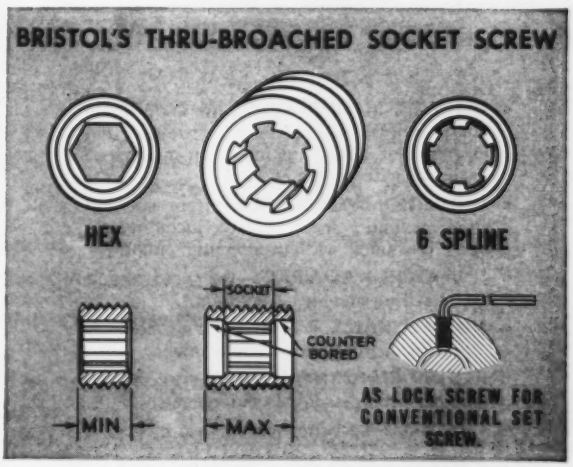

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Circle 622 on page 19

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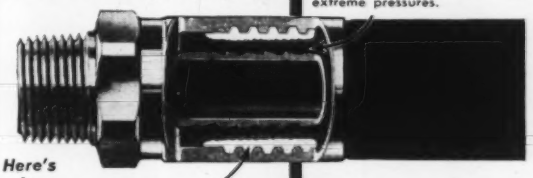

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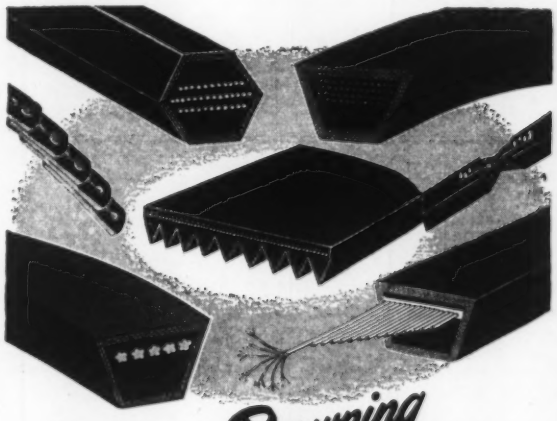

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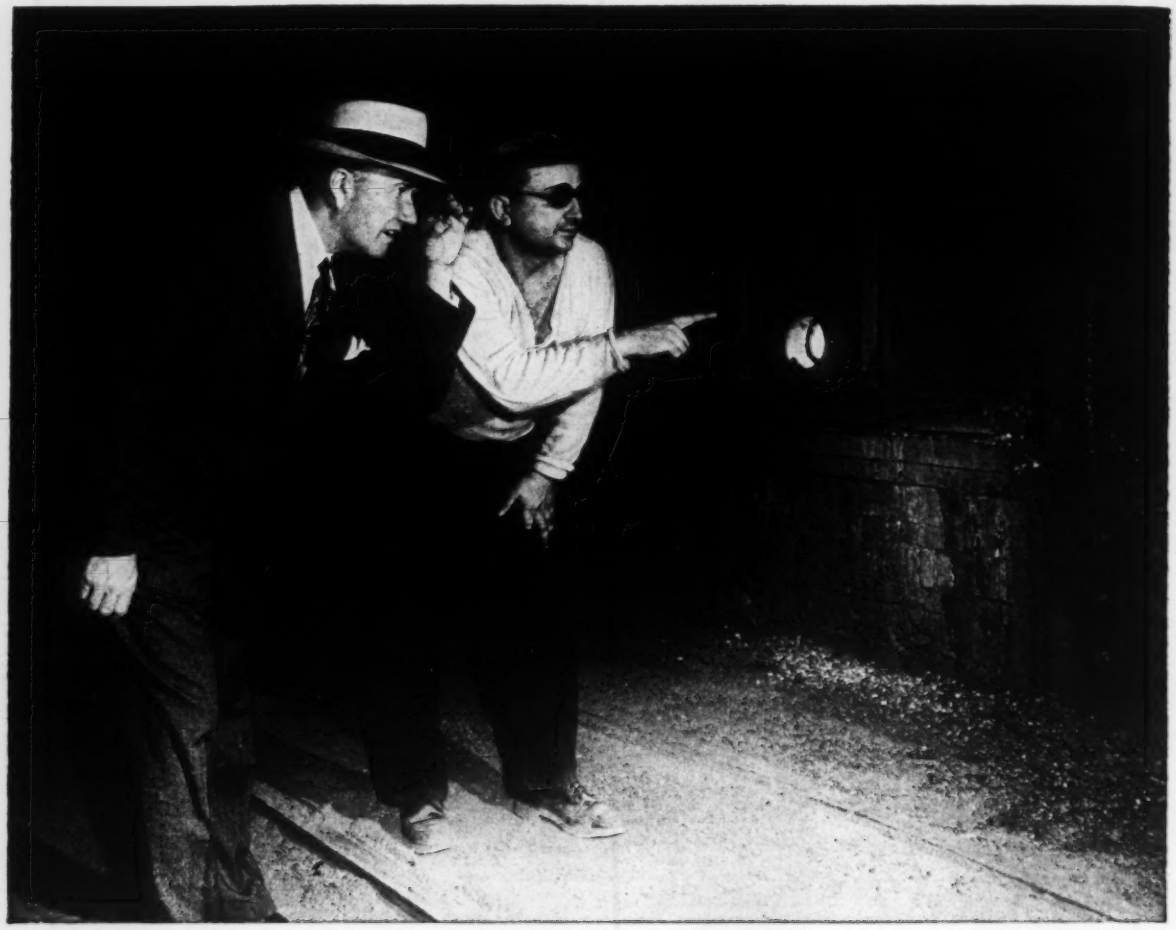

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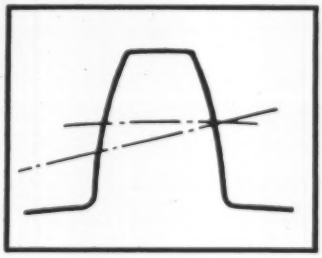
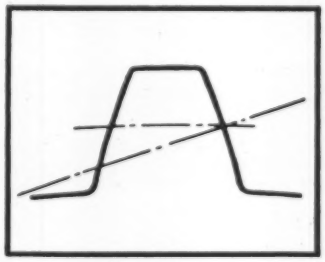
Advantages of Worm Gearing

By J. E. GUTZWILLER
Assistant Chief Engineer, Worm Gearing Department
De Laval Steam Turbine Company

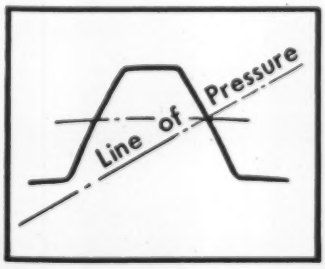
Interchangeability—The De Laval Steam Turbine Company was one of the first, if not the very first, manufacturer of heavy duty machinery to build worm gearing with interchangeable parts manufactured under limit gage control. Thus, worm and gear sets of like center distances but of different ratios can be readily interchanged if revision of speeds becomes necessary. Standard parts are always available for maintenance.



Standard 14½° involute spur gear tooth and old time worm tooth.



20° stub gear tooth.



De Laval Worm Gear Tooth. Note, line of pressure falls inside base of tooth.

High Shock Load Capacity—The worm gear tooth form is such that the gear teeth are under a crushing, rather than a bending load. For this reason extremely high momentary and shock loads, damaging to many forms of gearing, can be successfully withstood. High momentary overloads seldom cause failure, as worm gear ratings are figured on the wear resistance of the gear teeth.

Long Life—Bronze gear teeth maintain their correct form due to the regenerating action of the hardened steel worm, which retains its original shape throughout years of wear. A worm gear drive actually improves with service. This fact is peculiar to worm gearing and contributes to its recognized long life.

Smooth, Quiet Power—De Laval worm gearing transmits power by a continuous shockless action. Three or more teeth are in contact at all times, giving an even flow of torque and uniform angular velocity and eliminating vibration, pulsation, chatter and customary gear noises.

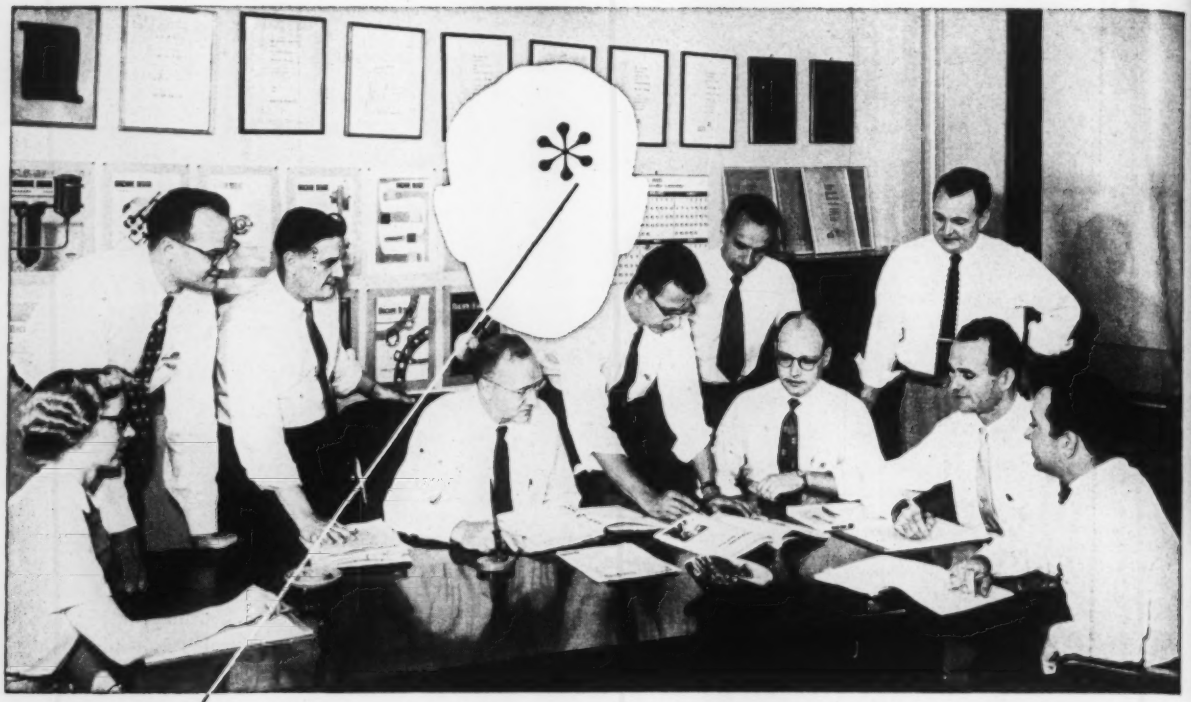
Compact Right Angle Drive—The use of worm gearing makes a neat, closely coupled, compact drive, with the motor shaft at right angles to that of the driven machine.

Larger Gear Ratios Simplify Design—Worm gearing offers larger ratios of speed reduction in a single compact set, another space-saving feature for the design engineer. The larger gear ratios obtainable in a single worm and gear set reduce the number of moving parts required.

Safety and Ease of Maintenance—The small number of moving parts in a worm gear drive may be readily enclosed, thus avoiding the hazard of exposed moving parts. Assuming proper lubrication, worm gearing operates with minimum attention, even under the most adverse conditions.

If you have a problem in the selection or application of worm gearing, De Laval engineers will be glad to put their experience to work for you. Either write us giving complete information, or consult your local De Laval representative. De Laval Steam Turbine Company, 858 Nottingham Way, Trenton 2, New Jersey.

DL 285R



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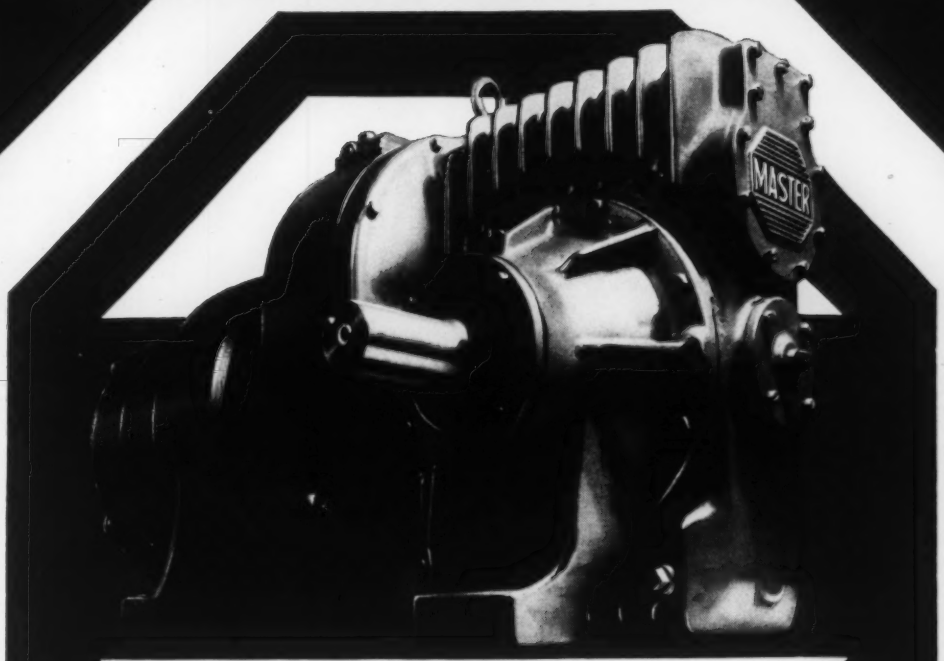

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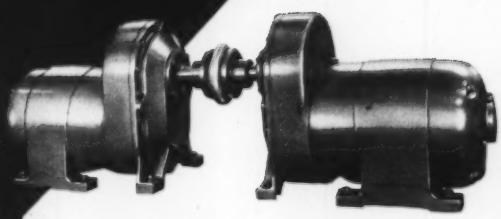

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